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AN EXPERIMENTAL INVESTIGATION OF THE VISUAL BEHAVIOR OF YOUNG HEROIN ADDICTS AND MATCHED CONTROLS

Robert J. Hall, et al

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The purpose of this experimentation was to determine if the eye movements of heroin addicts differed from non-addicted controls. The study employed an oculometer, which tracked and recorded eye movements without the subject's knowledge or any interference with his visual behavior, and a data processing system, which handled the large volume of data produced by tracking the eye at 60 frames a second.

Analysis of the eye movement data revealed major differences between the rapid eye movements, fixation sequences and scan pattern of addicts and non-addicted control subjects. It appears that the significant differences between the eye movements of the addicts and the control subjects are due to (1) motivational factors associated with the importance of the stimulus material; e.g., drug versus neutral items, (2) basic differences in the physiological and central nervous system processes that regulate eye movement., and (3) possible difference in reading skills and the ability to manipulate printed material. Extensions and application of the eye movement studies are discussed.

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AN EXPERIMENTAL INVESTIGATION OF THE VISUAL BEHAVIOR OF YOUNG HEROIN ADDICTS AND MATCHED CONTROLS[1]

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October 1973

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Aberdeen Proving Ground, Maryland

PREFACE

This unsolicited research effort was supported by the Advanced Research Project Agency under ARPA Order No. 2128 and monitored by the Behavioral Research Directorate of the U. S. Army Human Engineering Laboratory under Contract No. DAAD05-72-C-0720. The research made extensive use of the oculometer developed by EG&G for the Human Engineering Laboratory under Contract No. DAAD05-71-C-0182 which was being performed simultaneously.

ABSTRACT

The purpose of this experimentation was to determine if the eye movements of heroin addicts differed from non-addicted controls. The study employed an oculometer, which tracked and recorded eye movements without the subject's knowledge or any interference with his visual behavior, and a data processing system, which handled the large volume of data produced by tracking the eye at 60 frames a second.

Analysis of the eye movement data revealed major differences between the rapid eye movements, fixation sequences and scan pattern of addicts and non-addicted control subjects. It appears that the significant differences between the eye movements of the addicts and the control subjects are due to (1) motivational factors associated with the importance of the stimulus material; e.g., drug versus neutral items, (2) basic differences in the physiological and central nervous system processes that regulate eye movements, and (3) possible differences in reading skills and the ability to manipulate printed material. Extensions and application of the eye movement studies are discussed.

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AN EXPERIMENTAL INVESTIGATION OF THE VISUAL BEHAVIOR OF YOUNG HEROIN ADDICTS AND MATCHED CONTROLS

INTRODUCTION

The objective of this research was to conduct a series of experiments to determine (1) if the eye movements and cutaneous sensitivity of heroin addicts differed from non-addicts and (2) whether sophisticated instrumentation such as a remote oculometer could reliably identify the visual behavior that characterizes addicts. In addition, the study hoped to provide data on any long-term effects that heroin might have on visual behavior and related central nervous system processes.

The present investigation consists of a series of experiments conducted during two experimental sessions which occurred on different days. During these sessions heroin addicts and controls matched for age, sex and IQ were tested on the series of tasks developed in the early phase of the study. Table 1 indicates number of subjects used in each experimental task, the screening activities used, and the data which has been analyzed and reported in this report.

Selection and Screening of Subjects

Male and female heroin addicts were drawn from a population of approximately 2,500 addicts and dangerous drug users in the Las Vegas area.[1] The full cooperation of the local authorities was obtained and the assistance of the Las Vegas Metropolitan Police Department in the development of appropriate stimuli was instrumental in the accomplishments of the present investigation. The age range of the heroin addicts used as subjects was from 18 to 42 with a mean age of 25 years and the age range of matched control subjects was 18 to 38 with a mean age of 22 years.[2]

Drug History and Briefing

Since addicts in this population usually take a variety of drugs (Appendix A) determining the type and level of toxication is a major problem. In the present study, urine tests, interviews and drug histories were used to determine the subjects' drug use and level of toxication. Interviews revealed the approximate time of their most recent fix and obvious indices of drug use such as hypodermic tracks. The Drug History reveals that most of the subjects were at a level where they took heroin to keep from getting sick rather than to obtain a "rush" or euphoric state. During the initial briefing, addicts were given a code number to insure their anonymity and advised that they would be required for two sessions on different days and that the pay for each session was $20. They were also advised that a urine test was required to ensure that they were in

[1] This estimate is based on data supplied by local drug abuse and law enforcement authorities and does not represent an actual census.

[2] The authors wish to express their appreciation to the Department of Student Counseling and Placement at the University of Nevada, Las Vegas, for their assistance and cooperation in obtaining control subjects.

TABLE 1

Outline of screening activities and experimental tests used in Sessions I and II[a]

Screening Activities	Session I	Session II
Drug History and Interview	R, A	
Acuity and Flicker Test	R, A	
IQ Test	R, A	
Drug Jargon Questionnaire		R, A
Urine Sample	R, A	R, A
Sensory Test		
Cutaneous Test:		
1. Direction of Movement (5 and 10 grams)	R, A	R, A
2. Number of Cutaneous Subjects		
Addicts	28	28
Controls	28	28
Eye Movement Test:		
1. Word Recall Test		
(a) Observation Portion	R, A	R, A
(b) Recall Portion	R, A	R, A
2. Object Recall Test		
(a) Observation Portion	R, A	
(b) Recall Portion	R, A	
3. Split Word Test	R, A	R, A
4. Item Missing Test		R
5. Complex Scenes Test		R
6. Number of Eye Movement Subjects:		
Addicts	23	20
Controls	23	20

[a]The subjects used in Session I were the same as those in Session II; however, in some instances the total number is slightly smaller in Session II because addicts failed to turn up for the second session. The cutaneous test, direction of movement includes subject data from the earlier pilot studies. An "R" under the column for sessions indicates when the data was recorded. An "A" indicates that the data has been analyzed for this report. For a more detailed breakdown of how the data is partitioned and analyzed, see Figure 6.

fact true addicts and to assess their current level of toxication. Both controls and addicts were told that the objective of the research was basic sensory testing to determine whether any of the addicts' sensory processes had been affected by their addiction to heroin.

The Drug History and an interview concerning their drug use indicated that all subjects used marijuana and that there was an occasional use of cocaine, amphetamines and barbiturates. Interview questions concerning their use of marijuana indicated that it enhanced the effects of heroin. The interview also indicated that approximately 45 percent of the subjects were supplementing their heroin habit with methadone. However, at the time they served as subjects in the experiments, none of the addicts were in the local methadone program.

The routine toxicology screen using urine as a source was performed for the acid neutral group which includes barbiturates, tranquilizers, salicylates, etc., and for the alkaloid group which includes morphine, codeine, methadone, Demerol, etc. All of the subjects had urine assays which indicated morphine or morphine plus methadone in medium to high concentrations.

CUTANEOUS STUDIES

The test used to investigate differences in cutaneous sensitivity was developed by Langford, Hall and Monty (1973) and Hall, Rosenberger and Monty (1973). The experimental task involves the perception of a cutaneous track produced by a moving point on the skin. This task aided in adapting subjects to an experimental environment and provided data from a second sensory modality which could be compared with the eye movement data.

Cutaneous Experiment: Thresholds of Perceived Movement (5 and 10 gram stylus pressure)

The cutaneous experiment reported here has two aspects: first, the effects of the rate of movement on the perception of the direction of movement across the cutaneous surface; and second, the difference between heroin addicts and matched controls in detecting the direction of a point moved across the skin.

Procedure

In two sessions using 5 or 10 grams stylus point pressure, addicts and controls were asked to determine the direction of movement of a stylus point as it moved across the volar surface of the forearm. Prior to each trial the subject was alerted to the onset of the stylus movement, and as soon as he could determine the direction of movement he pressed a response button and reported the direction of movement. The response button stopped an electronic timer which indicated the distance that the point had traveled across the skin before the subject could detect the direction of movement. Each trial started with the stylus resting on the volar surface of the forearm and the direction of movement (toward the wrist or toward the elbow) and location of the starting point were randomized and counterbalanced. Each subject received a total of five trials per speed at a stylus point pressure of either 5 or 10 grams for a total of thirty trials per session. The stylus was moved at six speeds; 1.7, 2.5, 3.3, 5.0, 10.0 and 20.0 mm per second. The weight of 5 or 10 grams for the moving point was the same throughout a particular session; however, the selection of the weight for any particular session was counterbalanced.

Subjects

Subjects for the cutaneous experiment were 14 male and 14 female addicts and 14 male and 14 female controls, all of whom were right-handed. The addicts had an age range of 18 to 42 years with a mean age of 25 and the controls range from 18 to 38 with a mean age of 22. The overlap between subjects who participated in the visual and cutaneous experiments is not 100 percent because apparatus failures contaminated several subjects' data.

Apparatus

The cutaneous track apparatus is especially designed to automatically trace lines of a predetermined length and shape across the skin at constant speeds and pressures. The subject's right or left arm is inserted in an opening where it lays volar surface up on a felt covered metal cradle. This cradle is then raised until the arm comes in contact with a felt covered upper surface at which time it is locked and held firmly in place. Through a large rectangular opening, 5.5 cm x 26 cm, the stylus or moving point is brought in contact with the volar surface of the arm. Adjustments and controls are such that the stylus can be automatically lowered and moved across the volar surface of the arm for a predetermined speed and distance at which time it can be automatically raised. The subject sits comfortably in a chair with his arm inserted in the opening of the apparatus. All of the controls for adjusting the direction of movement, speed and location of the stylus are shielded from the subject's view. Through an appropriate selection of gears and electrical power settings, the stylus can be moved across the skin at rates ranging from 1.7 mm per second to 120 mm per second, and the weight or pressure of the floating stylus on the skin is adjustable from 5 to 200 grams.

Results and Discussion

Figure 1 shows the time required by the addicts and control subjects to detect the direction of movement when the point was moving across the volar surface of the forearm under 5 or 10 grams pressure. As the speed or distance traveled in millimeters per second is increased, the time required to detect the direction of movement decreased rapidly, $F(5, 260) = 122.27$, $p < .001$, and the direction of movement is detected more quickly for a heavier pressure of 10 grams than for a lighter pressure of 5 grams, $F(1, 52) = 27.37$, $p < .001$. Figure 1 also shows that for all conditions of pressure and speed, the time required for addicts to detect the direction of movement is consistently longer, $F(1, 52) = 17.55$, $p < .001$. The interaction between speed x addiction, $F(5, 260) = 9.38$, $p < .001$, and speed x pressure x sex, $F(5, 260) = 2.65$, $p < .05$, were also significant. From Figure 1 it can be seen that for the drug group the slower speeds produce a disproportionate lengthening of time required to detect the direction of movement.

Figures 2 and 3, which illustrate the sex differences between the drug and control group at 5 and 10 grams, indicate that for all speeds the male controls appear to detect the direction of movement more quickly than the female controls, and that this effect is more pronounced at the lighter pressures of 5 grams. The differences between the male and female addicts are not as pronounced.

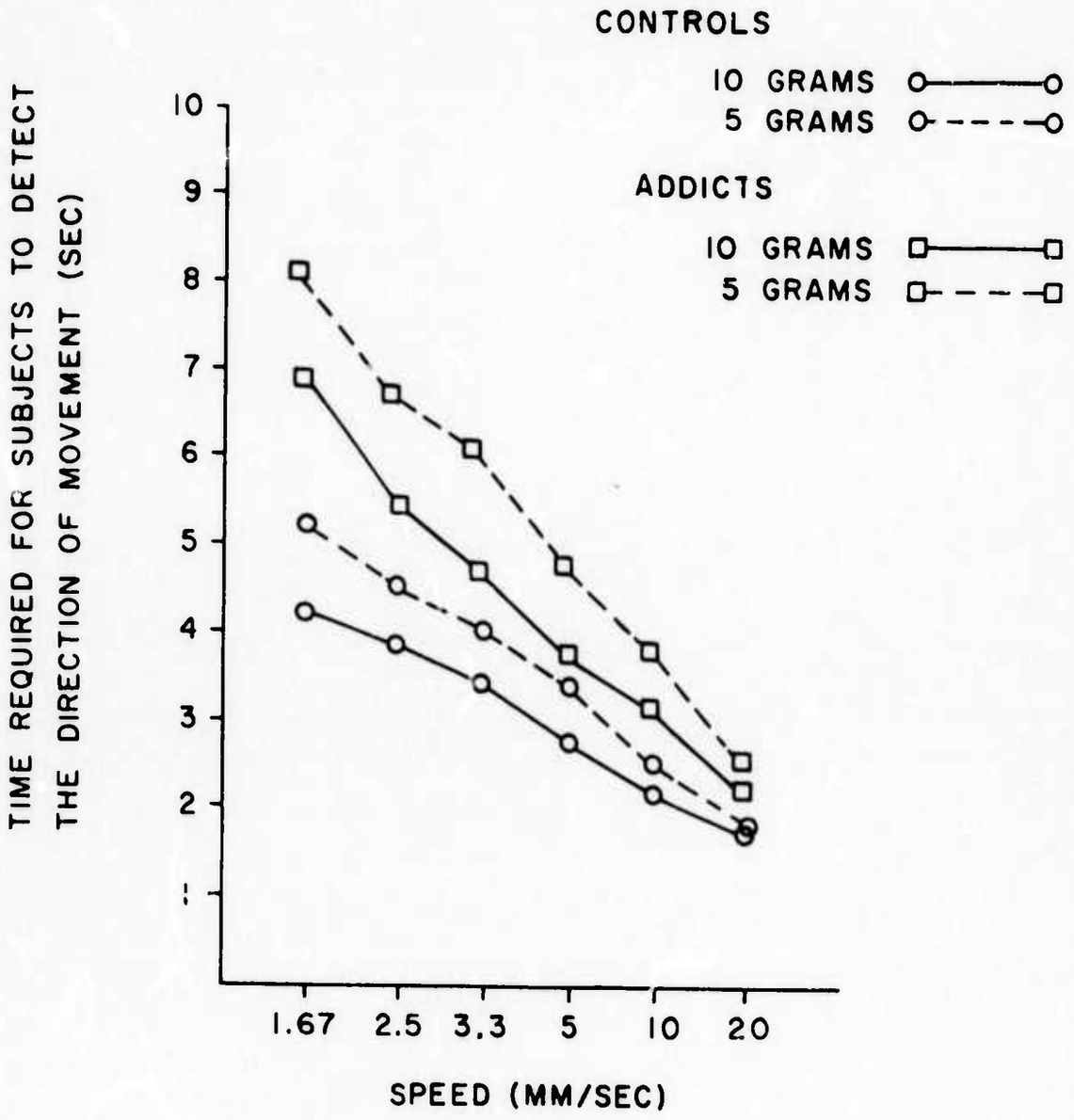

Fig. 1. This figure shows the differences between the addict and control groups (sig. .001) in detecting the direction of a moving point (toward the wrist or elbow) on the volar surface of the forearm. The time required for addicts to detect the direction of movement is consistently longer than the time taken by the controls.

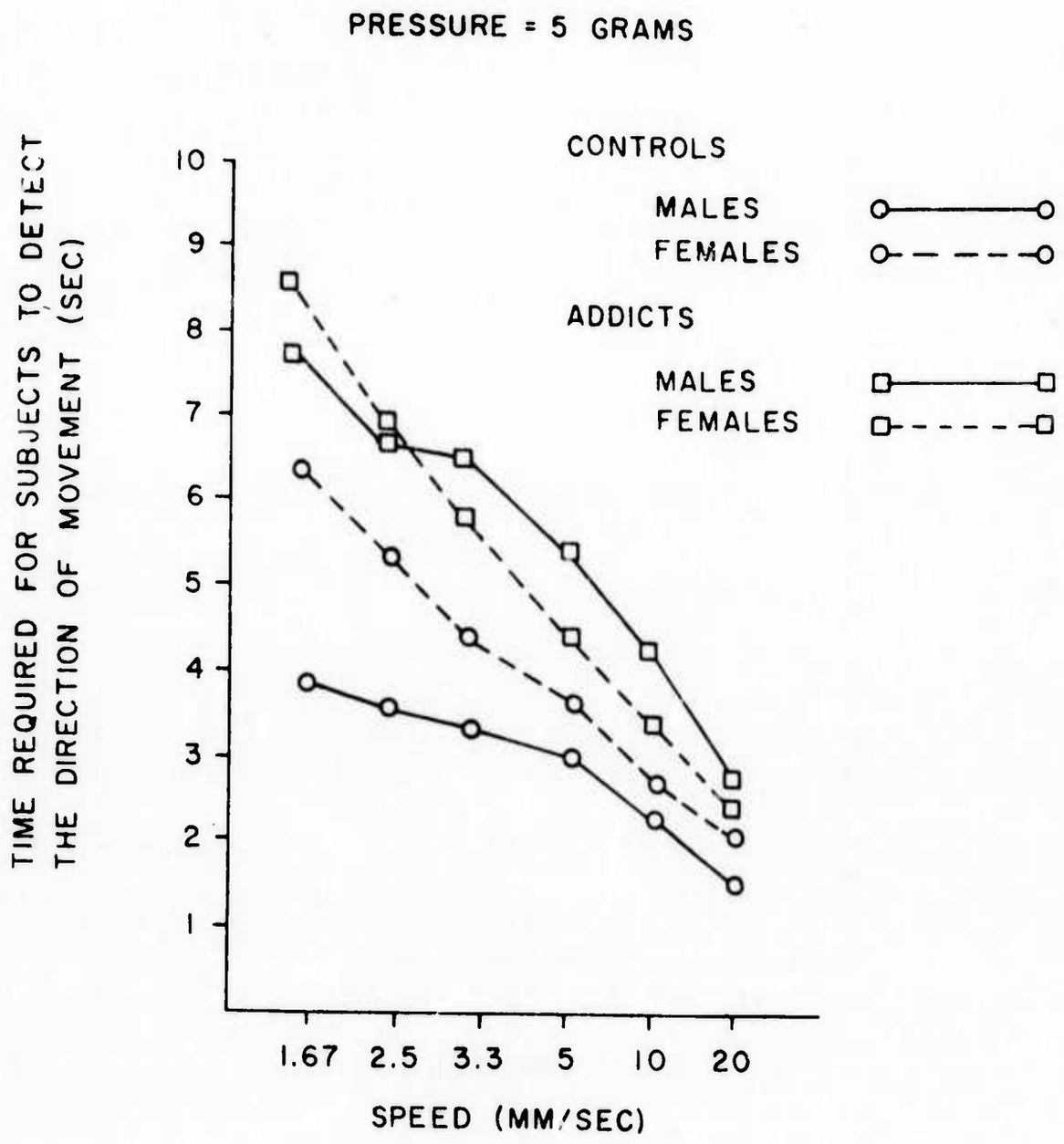

Fig. 2 This figure illustrates the sex differences between the control and addict group of subjects in time to detect the direction of a moving point on the volar surface of the forearm under five grams of pressure. (The male subjects appear to do consistently better than the female subjects and a comparison with Figure 3 illustrates that the female controls are more sensitive to pressure differences than the male controls.

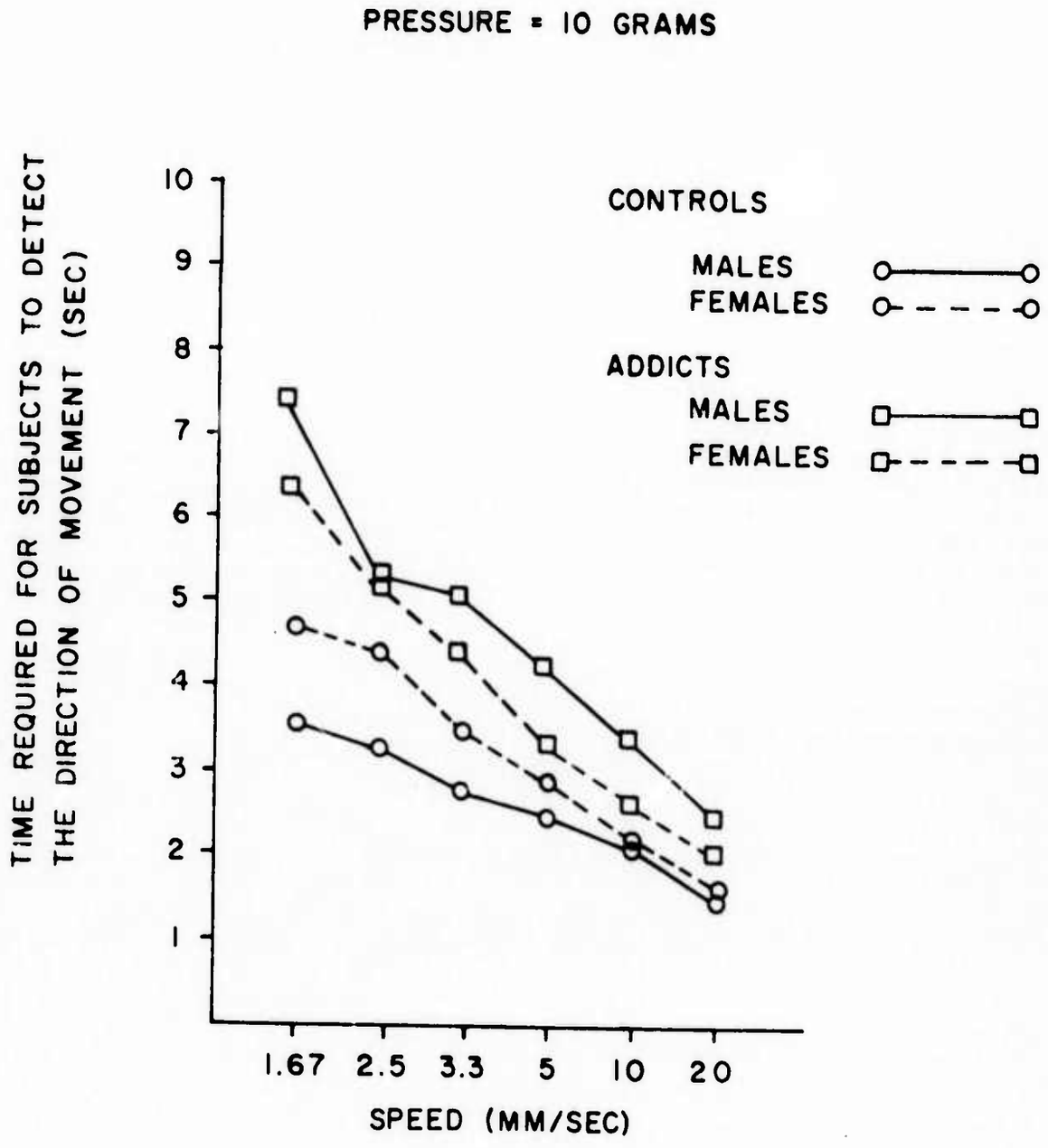

Fig. 3. This illustrates the sex differences between the control and addict groups of subjects in detecting the direction of a point moving across the cutaneous surface (mm/sec) at a pressure of 10 grams. (At this heavier pressure the differences between the male and female subjects are not as pronounced as at the lighter pressure (five grams).

An analysis of errors which occurred when the subjects reported the wrong direction of movement, is shown in Figure 4. This analysis illustrates that the average number of errors per subject for all speeds and stylus pressures was quite low. Secondly, the differences between the addicts and the controls were very small, suggesting that both groups were performing equally well on the task and that the differences between the addict and control groups' ability to detect the direction of a moving point on the cutaneous surface is not due to a motivational or attitudinal difference. These results suggest that the criterion used by both groups was the same and that the differences are due to some basic differences between the sensory processes of the addict and the control groups.

Conclusions

The dynamic test of cutaneous sensitivity used in these experiments suggests that there is a substantial difference between the speed with which addicts and control subjects detect the direction of a moving point on the cutaneous surface and a comparison of error scores indicates that both groups were striving equally hard to be accurate. If these differences are due to some functional or morphological difference in the sensory or central nervous system, it would seem likely that it is due to those processes that group or gate the incoming information; certainly the addicts appear to require more sensory data before they can arrive at the decision as to which direction the point moving. Since the differences are as great as four seconds at the slower speeds it seems unlikely that the differences between the addict and control group are due to differences in reaction time. In addition, the lighter pressures appear to affect the addict's perception of direction of movement to a greater degree than the controls' which suggest that as the information becomes poorer (lighter pressures) the addicts' information for detecting the direction of movement increases at a faster rate than that of the controls.

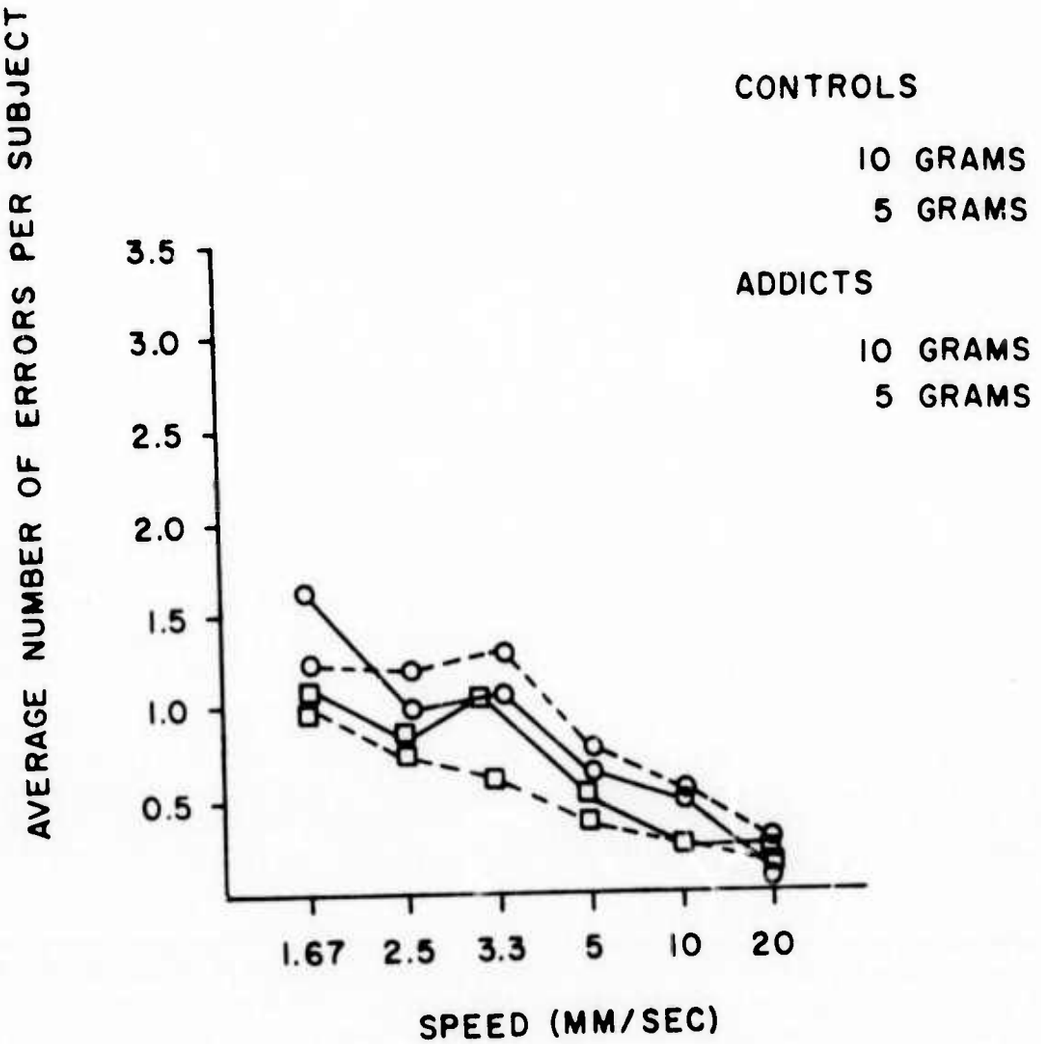

Fig. 4. This figure shows the average number of errors for the addict and control groups when reporting the direction of movement on the skin (i.e., toward wrist or elbow) . (As expected, the error levels are slightly higher for the slower speeds; however, there are no significant differences between the error levels of the addict and control groups. These results suggest that each group was trying equally hard to be accurate and that the differences obtained are not due to motivational factors.)

EYE MOVEMENT STUDIES

This section covers the nature of the experimental task used and the results obtained on the visual tasks. Eye movement and fixation data were recorded and measured by a new oculometer system (Appendix B) for 23 addicts and 23 non-addicts on five visual tasks in Session I, and 20 of the same subjects from each group in Session II. The visual tasks or tests as they are referred to in this paper can be conceived as distinct and separate experiments which cover visual behavior ranging from simple self-paced observation to high-speed scanning.

Preliminary Studies

In a series of preliminary studies on the visual behavior of nine addict and nine control subjects, Hall and Rosenberger (1973) reported that the visual behavior of addicts appeared to differ from matched controls in two important ways:

1. The addict subjects differed significantly from the control subjects in their basic scanning behavior and information sampling rate (fixation frequency and duration). The basic search patterns of addicts about objects or words appeared to be characterized by fixations dispersed over a larger area. In addition, the addicts' scanning behavior between multiple words and objects appeared to be less frequent than that of the controls who were more systematic in their scanning within and between objects.

2. When each subject's average fixation duration for neutral words and objects was compared with his fixation duration for drug objects and words, it was found that for drug words the addicts' fixation duration was always shorter and that the amount by which it differed from neutral words was always greater than the differences that occurred for non-addict control subjects.

The results of these preliminary studies showed that in addition to detecting the more volatile responses characterized by fear and intense interest, the relatively high-speed tracking of visual behavior, when accompanied by suitable data processing, could reveal differences in the visual information sampling that is related to basic processes inside the central nervous system.

Apparatus for Monitoring Eye Movements

At present, no single technique existing or under development can accurately record the entire range of eye movement without compromising or interfering with normal vision. Therefore, once the experimenter has defined his objectives, he must look at tradeoffs between a method's accuracy and the extent to which it distorts and constrains the natural scan patterns (Hall, 1972). For example, if the experimenter wishes to observe eye movements without severe postural constraints, he must be willing to accept tracking accuracies of plus or minus one degree at best. However, in many situations, lower accuracy can be compensated for by partitioning and distributing the stimulus situation that is under investigation.

Two of the major advantages of the apparatus used in this series of experiments are (1) it provides a technique for tracking and observing eye movement which does not interfere with the subject's normal viewing behavior (Fig. 5), and (2) it provides a data reduction capacity for handling large volumes of data. A detailed description of the oculometer and the associated data processing equipment is contained in Appendix B.

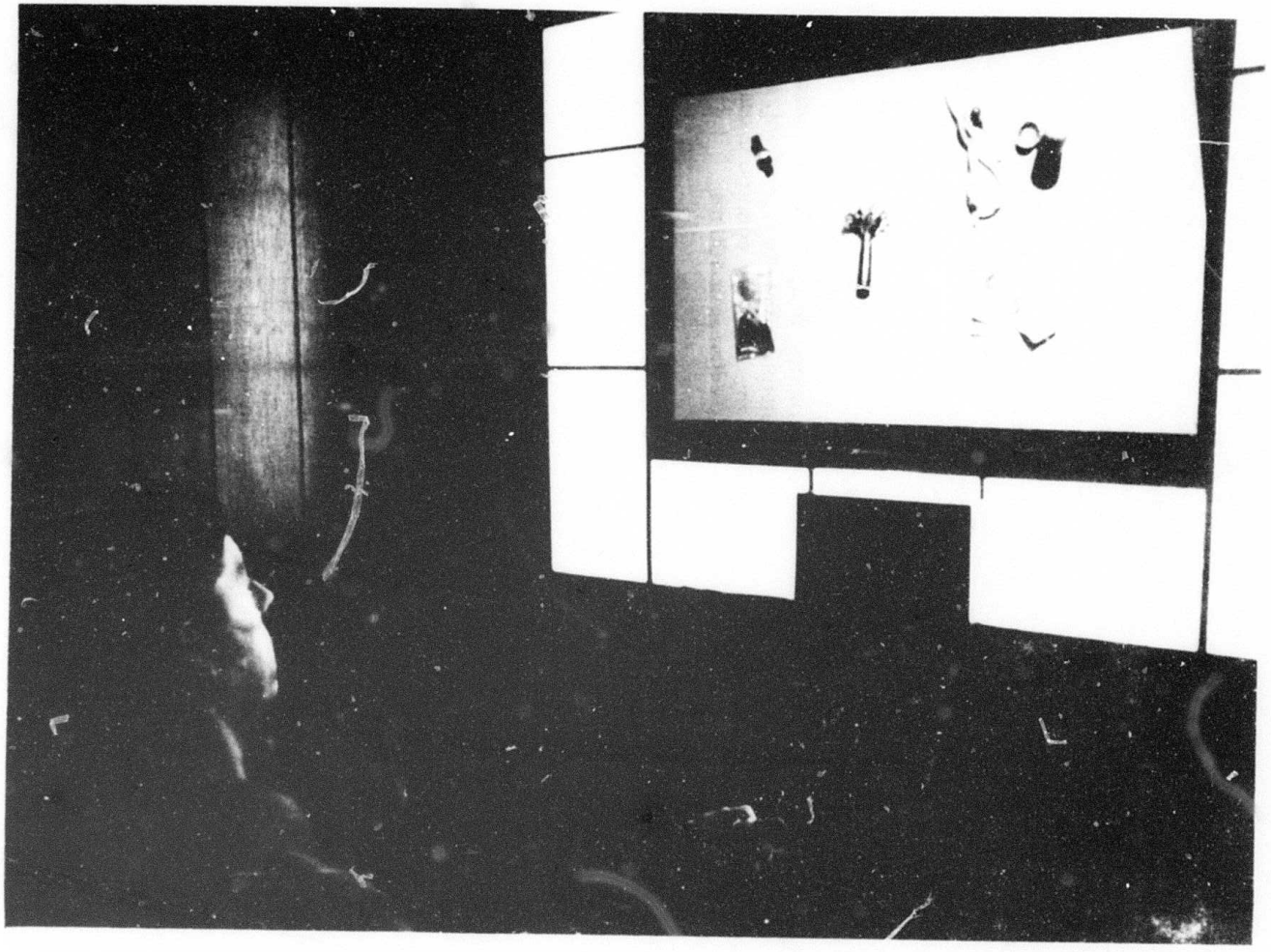

Fig. 5. Shows a subject seated in front of the oculometer looking at stimuli used in the drug object test. (The electro-optical sensor for tracking the eye movements is concealed behind a metal grill (black square below the screen), and the subject is holding a response button in his right hand.)

Dependent Variables and Factors that Define Eye Movement Data

The total eye movement data available on the five visual tasks used in Experimental Sessions I and II vary somewhat from subject to subject because some of the tasks were self-paced. However, the total viewing time per subject for all tasks combined was approximately 36 minutes or (60 frames per second) 129,600 frames per subject. For addicts and controls, this yields a possible total of 5,961,600 frames of eye movement data for the entire series of experiments. Some of these data were lost for a variety of factors; the subjects looked away from the screen, blinked their eyes, slide changes occurred, rapid saccades were not tracked accurately, etc. As a result the percentage of frames included in the fixation data output is approximately 63 percent, however this figure will vary as a function of the criterion used to define a fixation.

The basic data consist of the x and y positions of each fixation and the duration of these fixations. From this basic data, we obtained measures of the number of fixations associated with a particular stimulus location and the duration of each fixation associated with that stimulus. Information concerning fixation sequence and order (scan path) is also available; however, due to insufficient time it was not analyzed.

Data Reduction Program for Defining the Number of Fixations and Fixation Durations

This program operates like a complex filter which determines: first, what data is useable data (i.e., data which contains sufficient information to determine the eye's position); and, secondly, whether a sufficient number of frames are within the boundary conditions used to define a fixation. The shortest time used to define a fixation is six frames or 100 ms.

Data may be determined to be unuseable for a variety of reasons:

1. Highlight loss: (i.e., highlight is below the threshold set for defining its presence; for example, blinking produces highlight loss.)

2. Tracking error: (servo tracking error) In this instance the circle used to outline and track the pupil is not exactly over the pupil, and the discrepancy is sufficiently great to yield a spurious or distorted location of eye position.

3. Parity error: (e.g., video noise)

4. Operator override : Examples of where this occurs are gross head movement (e.g., laughing, sneezing). When the subject is not in view, he is brought back into the automatic mode by the operator's manual override.

The boundary conditions used to define a fixation are in terms of x and y (the horizontal and vertical coordinates of the derived point-of-gaze), and the number of useable frames that fall within the boundary criterion. For example, when the computer sees six or more consecutive frames of useable data within an x and y boundary of say 17x and 35y[3], it will record and print it out as a fixation. Other factors that determine the boundary conditions are:

1. Calibration data: Data which measured the natural geometric distortions which result from non-uniformities of the subject's cornea and changes in head position.

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[3]Since 2.5x or y equals approximately one degree, the dimensions of the 17x and 35y boundary criterion equals approximately 7 degrees in x and 14 degrees in y.

2. The spatial distribution of the stimuli: The actual distribution of the stimuli on the screen as occurred in the word recall test.

3. The nature of the visual task: Whether the task involves rapid scanning or normal search.

The manner in which the boundary conditions for determining a fixation are set, influences the nature of the data (i.e., the number of fixations and the average duration of the fixation). For example, our data indicates that there are basic differences between the number and duration of fixations for drug and control subjects, and that changing the parameters of the boundary conditions for the fixation program (what it will accept or reject as a valid frame associated with a fixation) causes it to operate like a complex filter which can enhance the differences existing between the drug and control groups. Differences in eye behavior that exist between the drug and control groups, and the effect of the boundary criterion used to define a fixation will be discussed for each of the experimental tasks.

General Instructions and Procedure

Subjects were told that the oculometer studio (Fig. 5) was designed to present visual and auditory tests, that the screen before them was designed to present visual tasks to the subject, and that the speaker below the screen (which conceals the oculometer's optical tracking system) was used for auditory tests. They were told that the chair in which they were sitting was placed so that each subject who looked at the visual stimuli or object presented on the screen would have approximately the same eye position and that it was important to look at the screen and attend to the test and not to look at the experimenter. They were given a hand-held button which was used to indicate that they had completed a trial. Subsequent interviews revealed that all subjects were unaware that they were being observed by the oculometer.

Calibration data for the oculometer was obtained by having subjects view a Troxler calibration slide which consisted of a dark background with four dots, one in each corner of the slide. The subject was instructed to stare at one of the particular colored dots and then to report the disappearance or change in any of the other three (Troxler effect)[4]. This procedure was repeated for each of the four dots in an upper left, upper right, lower left, lower right corners of the screen. This task provided excellent calibration data and since the disappearance and fading of the dots in the peripheral portion of the visual field is a very real phenomenon, the actual purpose (calibrating the eyes of the subject) was easily obscured.

Word Recall Test

The intent of the word recall test was not to study recall but rather to expose addicts and control subjects to a variety of words to which they may be sensitive and observe their eye movement when such words appeared at four points on the screen. Three categories of words were used, neutral words taken from a common association list, drug jargon taken from the drug jargon questionnaire developed by Dr. Robert Earl[5] and the so-called "dirty words" which

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[4]This common phenomenon of fading or diasppearance of an object in the periphery occurs frequently when the eyes are held steadily on a fixation point. It is closely related to the disappearance of objects when they are stabilized on the retina, i.e., stabilized image.

[5]Currently Dr. Robert Earl is Director of Evaluation Mental Health Dept., Center for Special Problems, 2107 Van Ness Ave., San Francisco, California.

consist of words having a double meaning, e.g., screw, cock, etc. (see sample below). During each of the two experimental sessions, subjects were shown twenty-four four-word slides containing various combinations of these word categories.

GEEZE CANDY

BACON SCREW

Each slide containing four different words was displayed for eight seconds and then replaced by a new slide which appeared for the same amount of time. The subjects were told that following the presentation of these slides, they would be tested to see how many tney could remember having seen before. In the recall session, thirty-six two-word slides were presented one at a time. For each two-word slide, the subject was asked to press the response button, and to say the word aloud if he had seen one of the words before or to press the button and say "No" if he had not seen either word previously. On the recall portion of this test, a total of thirty-six two-word slides were presented to the subjects; twelve words were drug words, six of which had been seen and six which had not been seen before. The same seen and not seen arrangement was used for the twelve dirty and twelve neutral words. A group of twelve neutral words was selected for comparison with the twelve drug and twelve dirty words.[6] During the first and second portion of the word recall test (the automatically paced twenty-four four-word slides and the thirty-six self paced two-word recall slides), the eye movements were tracked and recorded by the oculometer at 60 frames per second.

Results: Word Recall Test, Observation Portion, Session I

Experimental Sessions I and II of the word recall test occurred on different days. Different drug, neutral, and dirty words were used but the slide format in both sessions was identical. Each session produced two sets of data. The first set of eye movement data was associated with the observation of twenty-four four-word slides. The slides were presented in sequence to the addict and control subjects for eight seconds each. The second set of data consisted of the eye movements associated with the two-word recall slides during which time the subject decided whether they had seen one of the words in the preceding series of four-word slides.

In the preceding sections of this report, it was pointed out that there are a variety of criteria that can be used to determine what is a fixation and that the boundary criterion tends to act like a selective filter which emphasizes the basic differences in the scanning behavior of addicts and control subjects. In the present study, it was decided to use two boundary criteria (17x 35y and 4x 7y).

Figure 6 shows how the eye movement data from the first part of the word recall test has been partitioned and analyzed. For each criterion used to define fixations, the data is broken down into two basic analyses: the between groups and the difference score analysis. The between groups analysis compares differences in the number of fixations and the duration of fixations for word position. The difference score analysis compares each subject's eye movement responses on a critical item to his average responses on neutral items which occurred at the same position as the critical item. After the differences in each subject's responses to critical items has been determined, the addict and control subjects' data are summarized and compared to evaluate group differences.

[6] In addition, the twelve drug, dirty, and neutral words selected for analysis were paired with a second neutral word on the two-word slides which had not been seen before. However, the eye movements for this particular group of words has not been analyzed.

As indicated by Figure 6, each distinct set of data can result in eight separate analyses. For the word recall test which has two sets of data in each experimental session, this could result in a total of thirty-two separate analyses; however, because of time constraints, we have restricted the analyses following the first set of word recall data.

The Effect of Word Position on Fixation Frequency: The mean number of fixations for the addicts and control subjects using a data processing boundary criterion of 17x and 35y is shown in Figure 7. As was expected, the number of fixations for the upper right and left are somewhat higher than those at the lower left and lower right. Although the differences between the positions are significant $F(3, 132) = 48.41$, $p < .001$, they are largely due to nonlinearities of the cornea and their effects on the system's tracking accuracy. A statistical comparison of the differences in the number of fixations between the drug and control groups are significant, $F(1, 44) = 8.81$, $p < .001$.

A second version of the word recall test was given to twenty of the same subjects during the second session and the results essentially replicated those obtained during the first session. Once again, a between groups analysis of the frequency of fixations for all four word positions, upper left, upper right, lower left, and lower right indicated significant differences for word location $F(3, 144) = 32.75$, $p < .001$ and the number of fixations between the drug and control groups. was also significant $F(1, 38) = 12.27$, $p < .001$. Figure 12 shows a comparison of means for the four locations on the four-word slides for both versions of the word recall test. It should be pointed that the slightly different degrees of freedom for the first and second sessions are because three addicts who took the first version did not show up for the second session. This resulted in a group of 20 addicts and 20 controls who took both versions of the test.

These results of Figures 7 and 8 suggest that for the boundary criterion of 17x and 35y, a greater number of the addicts' fixations were being combined into a single fixation than those of the controls. It also suggests that the scanning behavior of the two groups differed and that the control subjects might be scanning from word-to-word more frequently than the addicts.

Average Fixation Duration: Figure 9 shows the average duration of fixation at each of the four positions where the words were located. The top two curves (boundary criterion of 17x and 35y) indicate that the average duration of fixations is in the neighborhood of 40 frames per word and that the mean duration of the fixation is significantly longer for the addicts than the controls, $F(1, 44) = 9.30$, $p < .001$. The between group analysis of fixation duration on the second version of the word recall test given during the second session, appears to replicate the results obtained on the first test. A subsequent analysis of the word category (neutral, drug or dirty) on the data shown in Figure 9 suggests that the differences in fixation duration are substantially longer for the drug and dirty word categories and that the differences between the addicts and control subjects are larger for these categories than the neutral word category.

Results: Difference Score Analysis, Observation Portion of Recall Test

This analysis of unique responses to drug and dirty words is based on a difference score analysis in which the subject's response to neutral words is taken as a baseline for comparing his visual responses to the drug and dirty words.

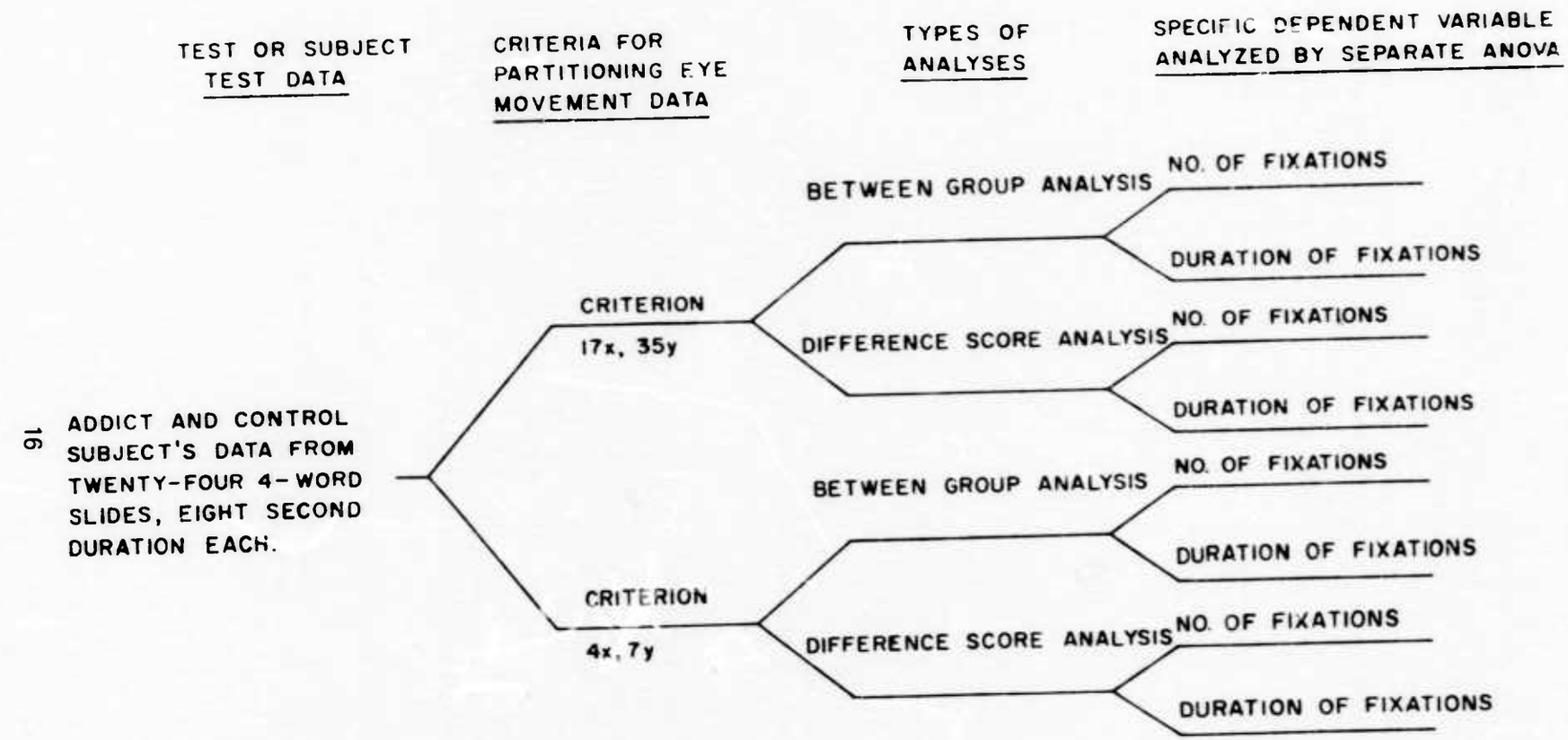

Fig. 6. This schematic illustrates how a set of addict and control subjects' data is analyzed. (First, two criterions used to determine a fixation, are selected (17x, 35y and 4x,7y). This data is partitioned further into two types of analyses. The between groups analysis compares each group's number of fixations and fixation durations for word location, and the difference score analysis compares each subject's eye movement responses on neutral and critical items.)

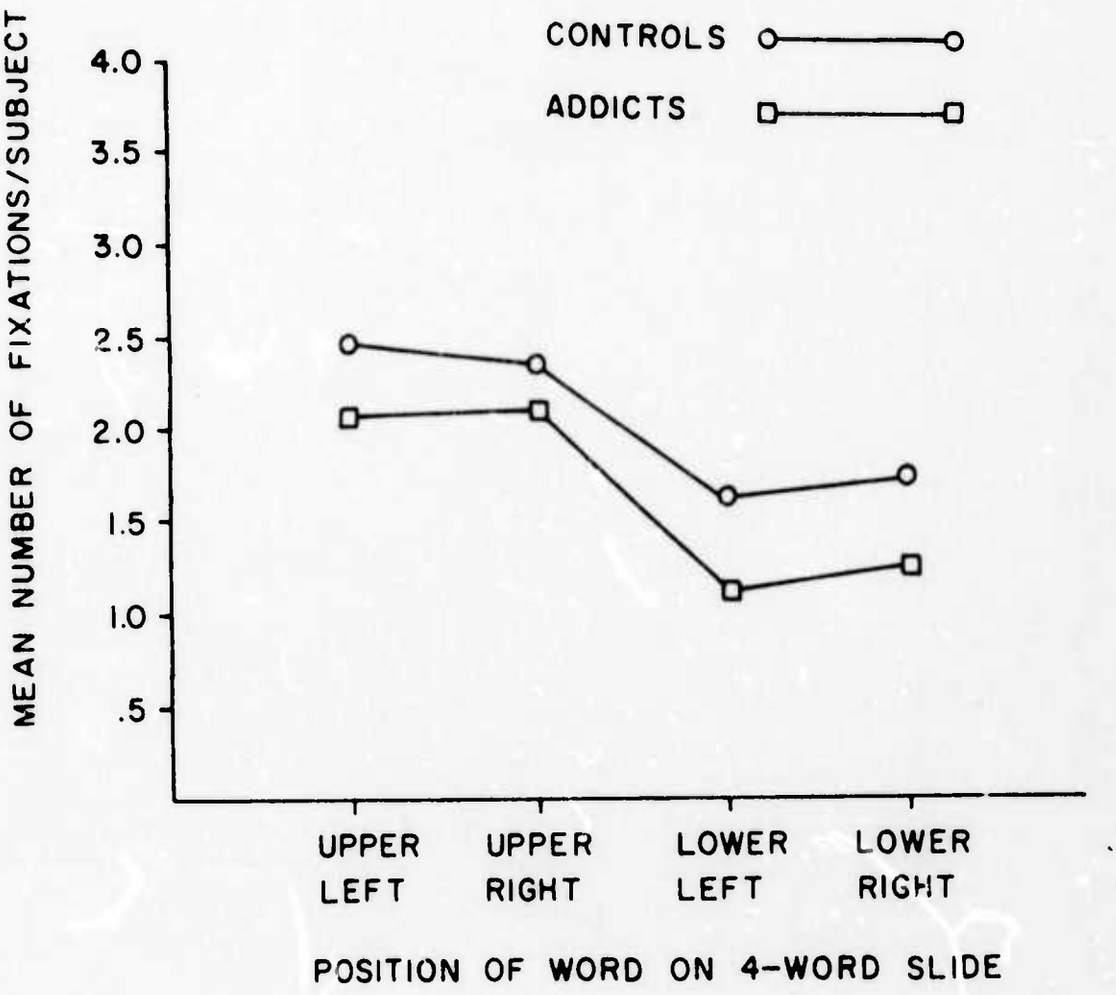

Fig. 7. This graph shows a mean number of fixations for the drug and control groups at the four positions where the four words were located. (For this figure, a spatial boundary criterion of 17x and 35y was used to define a fixation, six or more consecutive frames (100.2 ms) with accurate tracking. From this graph, it can be seen that there are substantial differences in the number of fixations per word position for the addict and control groups (significant at the .001 level).)

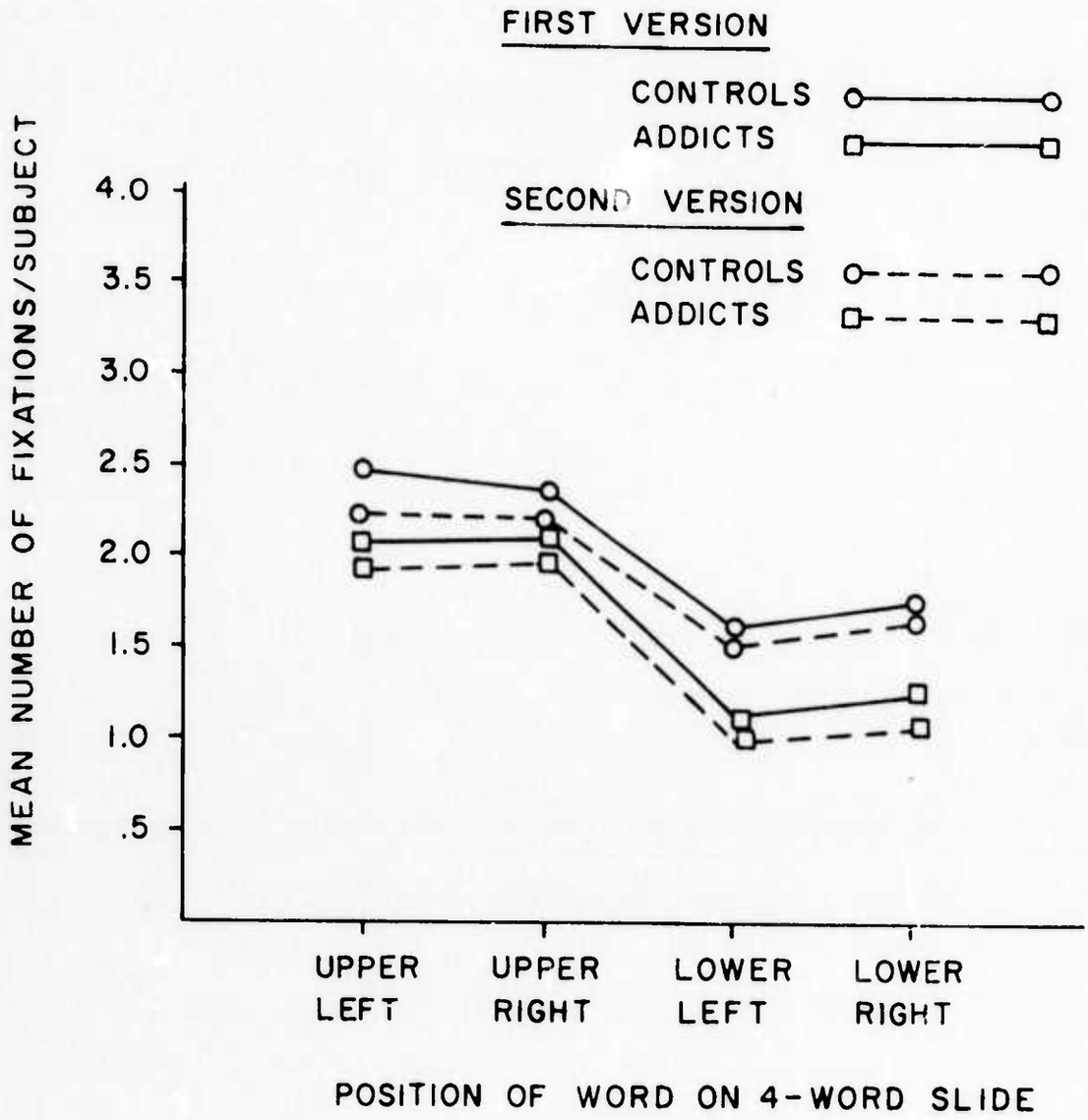

Fig. 8. The results from the two versions of the word recall test are shown here. (The data are for the observation portion which uses four-word slides. The results for the second version replicate those obtained in the first; namely, the differences for word location $F(3, 144) = 32.75, p < .001$ and differences in the mean number of fixations between the addicts and controls are in the same direction and highly significant $F(1, 38) = 12.27, p < .001$.)

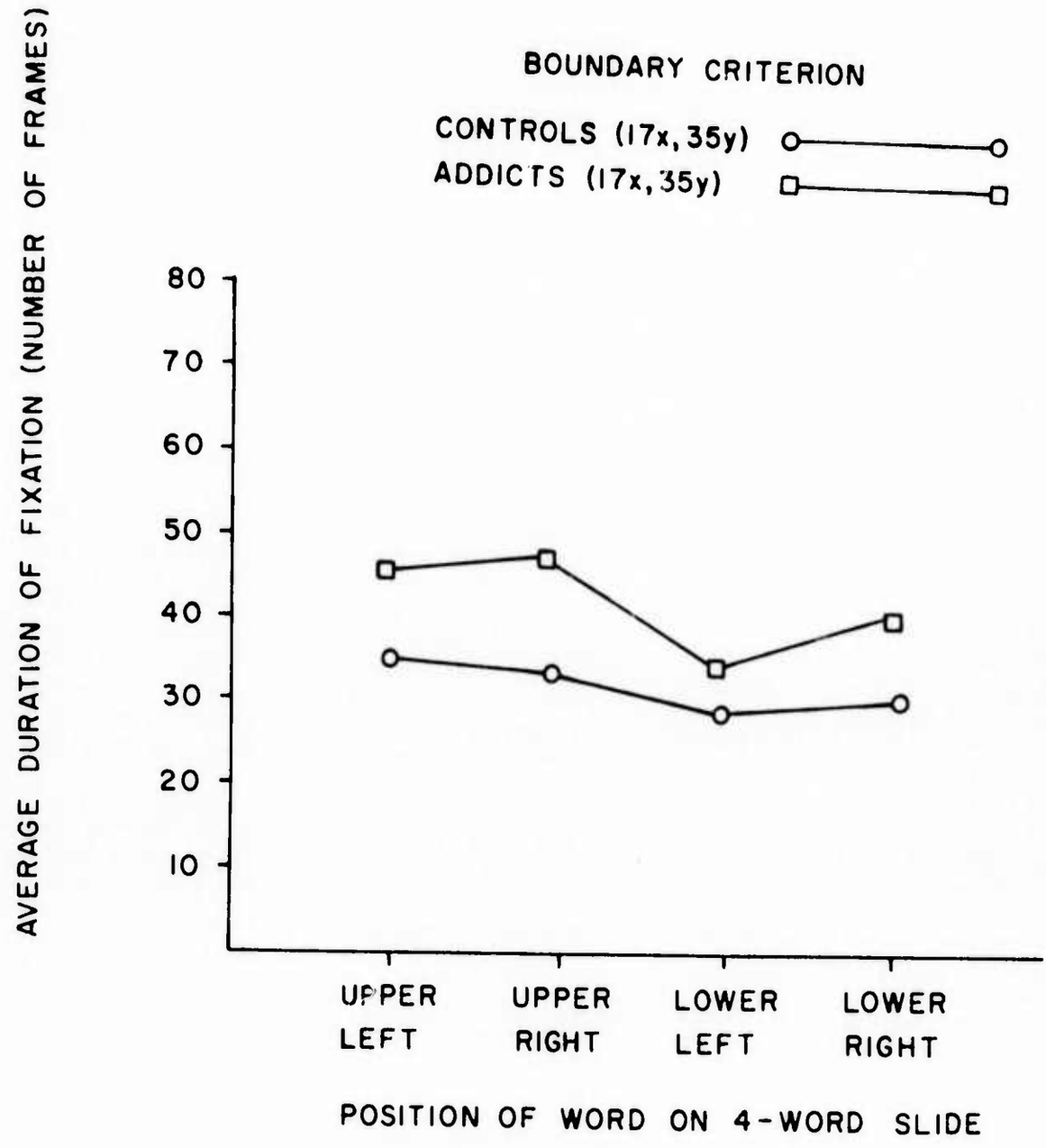

Fig. 9. The upper portion of this figure shows the difference in fixation duration when the eye movement data are processed by a boundary criterion of 17x and 35y. (In this instance, we see the larger gate tends to summarize the sequential fixations of the addicts because they tend to occur more frequently around any one word. In the case of the controls, it appears that this occurs to a lesser extent because they scan more frequently between words.)

When the differences between the individual subject's means for neutral words and drug or dirty words are combined into grand means for the addict and control groups (Fig. 10), we see that the addict group is responding to the drug and dirty words with fixations of longer duration than their fixations for neutral words, while the control subjects' fixations are close to their mean fixation for neutral words and longer or shorter in duration than their fixations for neutral words.

The differences between the addict and control groups shown in Figure 10 are significant for both drug and dirty words, $F(1,44) = 16.79$, $p<.001$.

The results of this difference score analysis in which each individual's response to neutral words is used as a baseline suggests that this would be a valuable technique in screening individuals when the stimuli may have some strong emotional value as in the case of deception and fear.

Results: Word Recall Test, Recall Portion, Session I

Figures 11 and 12 show the average duration of fixations in frames per second (1 frame = 1/60 of a second or 16.67 ms) during the recall portion of the word recall test for the neutral, drug, and dirty word categories. Figure 11 contains the data for both versions of the word recall test used in Sessions I and II. In this portion of the test, the subjects viewed a sequence of thirty-six two-word slides containing twelve neutral, twelve drug and twelve dirty words. Six words in each group had been seen before and six had not. The subject's task was simply to say the word aloud and press a response button if he thought that he had seen it during the preceding observation portion of the word recall test. In all slides, each test word was paired with one other neutral word that had not been seen before. The eye movement data for these neutral words was not analyzed.

Using a boundary criterion of 17x and 35y to define a fixation, Figure 11 shows that there is a difference in average duration of fixation between the addict and control subjects for the three classes of words. The average duration of fixation is 37.87 frames (60 frames = 1 second) for controls and 48.01 frames for addicts, $F(1, 44) = 4.66$, $p<.05$. The interaction (see Fig. 12) classes of words x seen and not seen, is also significant, $F(2, 88) = 4.03$, $p<.05$ which indicates that for the drug and dirty classes of words the addict and control subjects are responding differently. Both addict and control subjects tend to look longer at the drug or dirty words that they have seen before. There are little or no differences between the neutral words that were seen or not seen before.

A similar analysis for fixation number using a boundary criterion of 4x and 7y which reflects a difference between the addict and the control subjects in number of fixations showed that the mean number of fixations for the control subjects was 3.78 and the mean number for the addicts is 4.86, $F(1, 44) = 4.74$, $p<.05$. For number of fixations, there are no significant differences between word groups but both groups have more fixations for the drug words that have been seen before. The significant differences in number of fixations in the recall portion of word recall probably occurs because it is a self-paced task and the addicts take longer to read the material and make a decision.

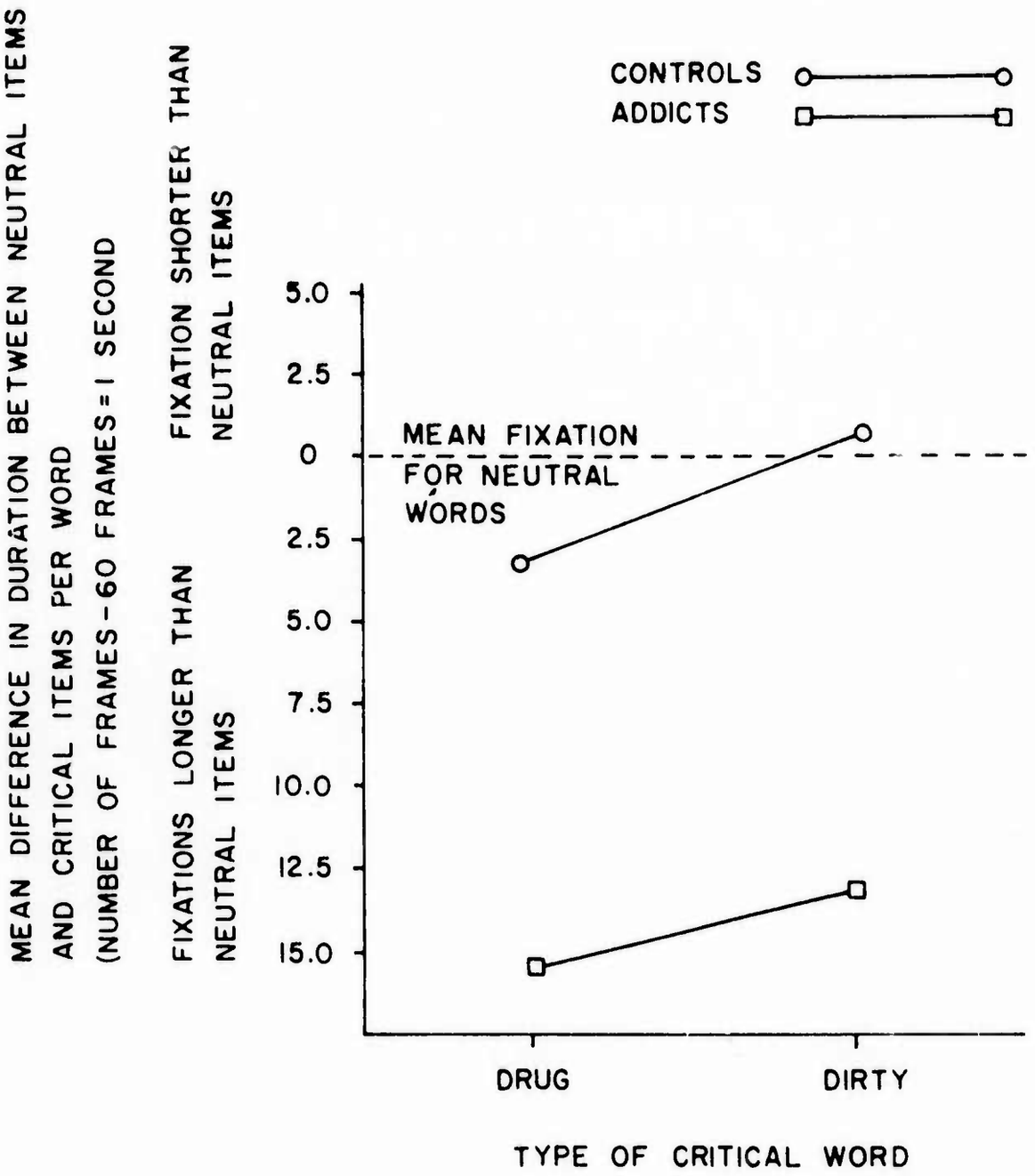

Fig. 10. This figure shows the differences for drug and control subjects when their own fixation duration for each drug and dirty word is subtracted from their own average duration for neutral words. (To obtain this data, a mean difference in duration for each class of critical words at each of the four locations on the slide was computed for each subject and then a grand mean for groups was calculated. Each group's mean for neutral words is represented by the dashed zero line on the graph. A comparison of the addicts' curve with one for controls shows that this analysis reveals substantial differences between addicts and controls in their responses to drug and dirty words; namely, the addicts' differences in fixation duration from their average duration for neutral words are longer than the controls and always in the positive direction $F(1, 44) = 16.79$, $p < .001$. The differences for the controls are close to the mean for neutral words and in both directions.)

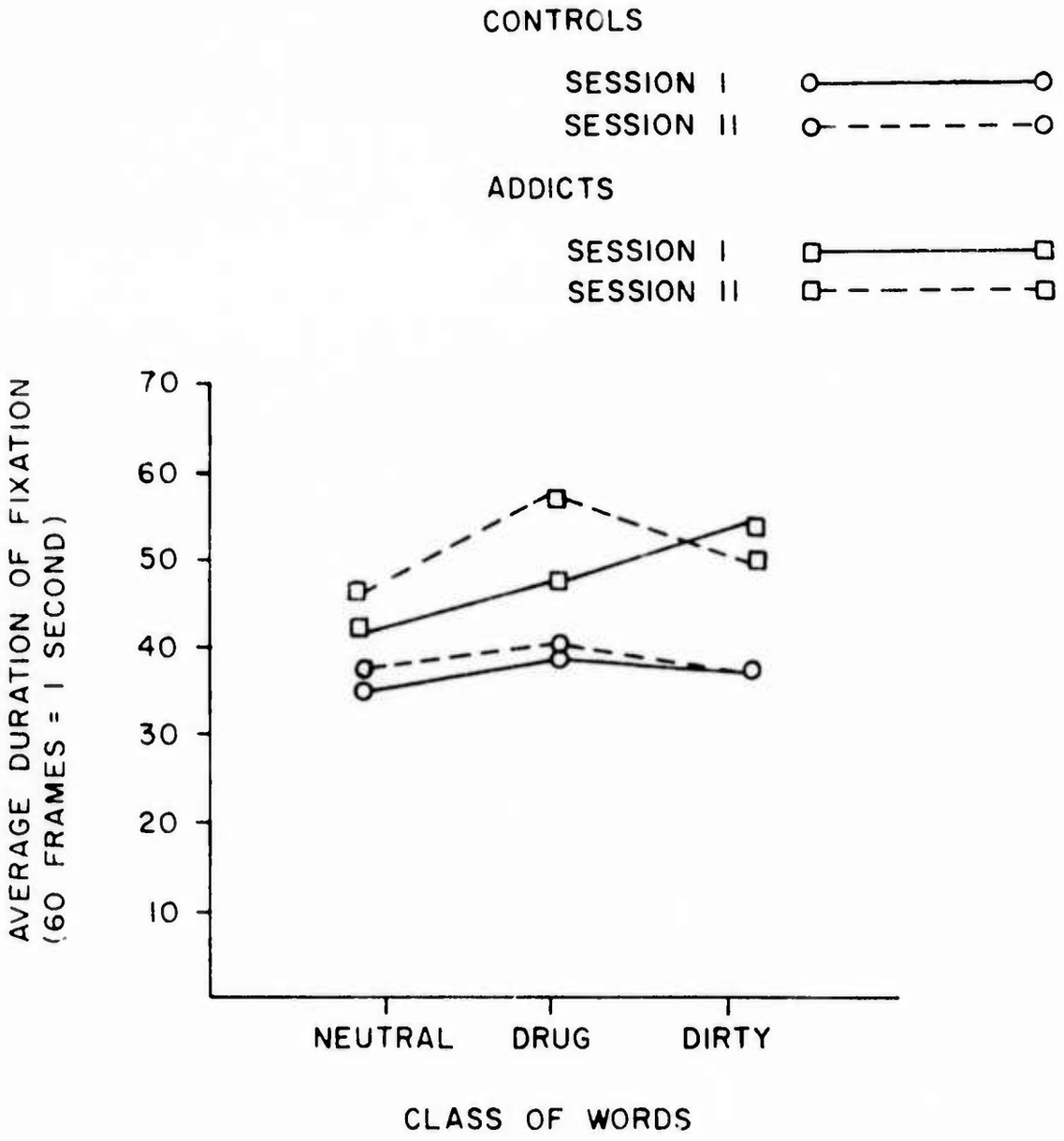

Fig. 11. This figure shows the differences between the addict and control subjects' average fixation duration on the recall portion of the word recall tests used in Sessions I and II. (Note that Session II results replicate those of Session I.)

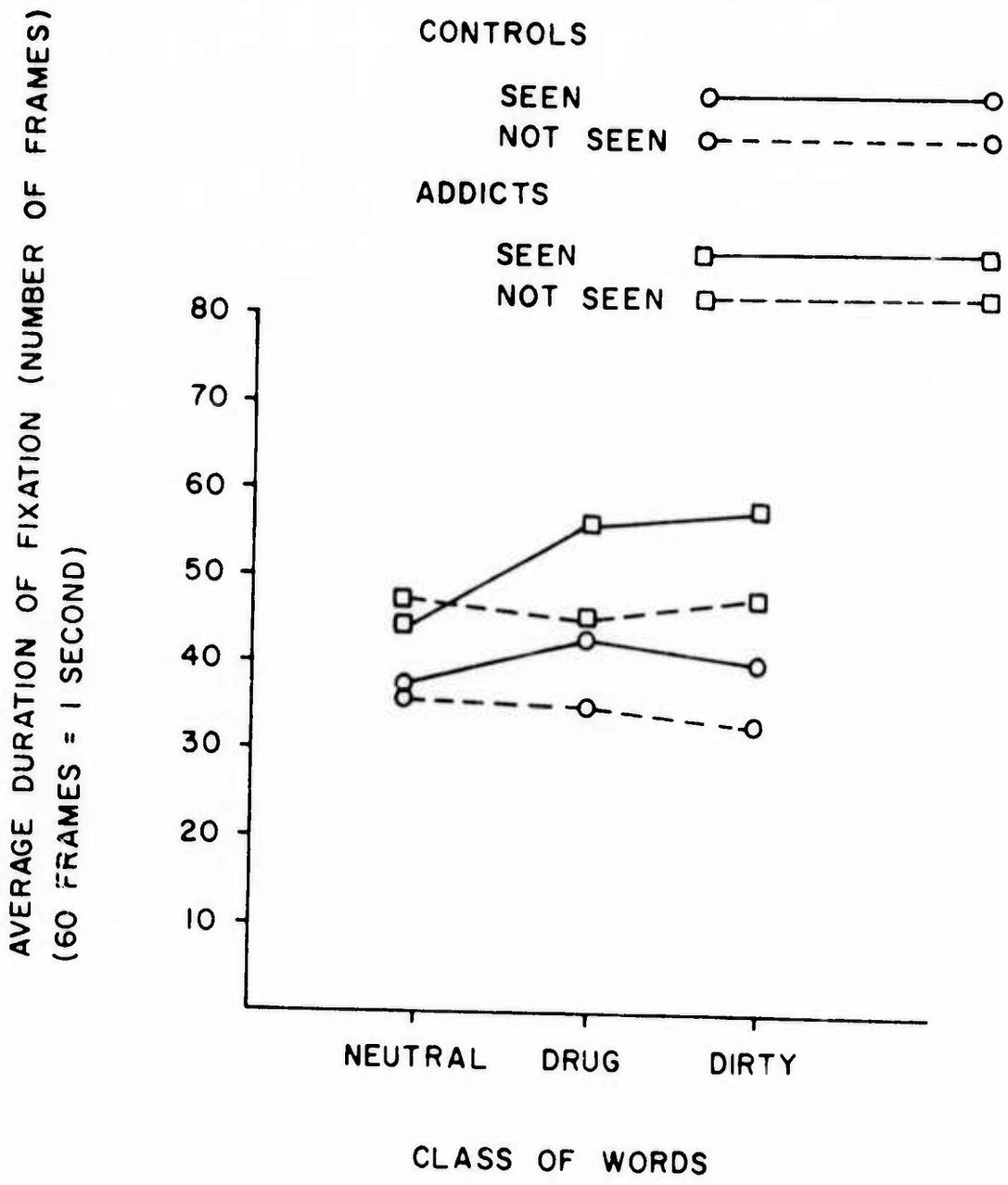

Fig. 12. The graph for the recall portion of the word recall test shows the differences in fixation duration between the addict and control subjects on neutral, drug, and dirty words that have and have not been seen before (sig. .05 level). (The seen and not seen factor has a substantial effect on both the drug and neutral groups. The curves for this figure are based on the results from both versions from both versions of word recall test, 23 subjects per group in Session I and 20 in Session II.)

Conclusion from Word Recall Test

The analyses which have been completed for the second version of the word recall test used in Session II essentially replicates the results obtained with the first version in Session I (Figs. 8 and 11). The between groups analysis of the four positions where the stimuli in the four-word slides were located, indicates that there are substantial differences between the addict and control group in fixation duration and fixation frequency for neutral, dirty and drug words. Since each subject looks at each slide for the same period of time, this suggests some difference in their scanning behavior. A subsequent analysis reveals that the differences in fixation duration are larger for drug and dirty words than neutral words; however, the differences between addicts and controls still exist for the neutral word category in both versions of the word recall test. This suggests that in addition to the differences produced by the motivational aspects of the drug and dirty words, there may be differences caused by basic differences in the rate at which such material is scanned or processed by the addict group. Although the acuity and IQ tests do not indicate what these factors might be, it is possible that some basic difference in sensory processes or reading skills could account for the difference in fixation duration on neutral words.

The difference score analysis of fixation duration indicates that the individual addict's response to drug and dirty words is different from his response to neutral words and that the controls are not (Fig. 10).

Major differences also exist between the addicts and controls in terms of fixation duration and frequency on the recall portion of the word recall test. Since this is a self-paced task and the addicts take longer to recognize a word, we would expect them to have a larger number of fixations. However, this will not suffice to explain the differences in fixation duration on the simple recall slides which only contain two words (Fig. 11). The seen and not seen parameter (fig. 12) appears to have an effect in that average durations are longer for the not seen drug and dirty word categories. In other words, both the controls and addicts appear to take longer to recognize a previously seen dirty or drug word, and the difference between seen and not seen is greater for the controls. The differences in fixation duration between the addict and control groups (Figs. 11 and 12) in what is a very simple stimulus situation (two-word slides) suggest that some basic physiological or structural mechanism is operative.

Object Recall Test

The general procedure for this test was identical to the word recall test in that the first series of four item slides of neutral and drug objects were presented to the subject once every eight seconds. Twenty-four slides were presented which contained neutral or drug related material. Twenty slides contained drug objects at one of the four positions in random order and four of the slides contained only neutral objects. During the recall session, certain drug and neutral items which had been seen and not seen were presented paired with a neutral object and the subject was asked to report verbally "yes" or "no" and press the response button as soon as he was sure that he had or had not seen the object before.

Results: Object Recall Test, Observation Portion, Session I

The results of the between groups analysis for the object recall test are shown in Figure 13. As in the word recall test, the difference between controls and addicts in number of fixations is significant, $F(1, 44) = 6.21$, $p < .001$. The location or position of the object on the slide is also

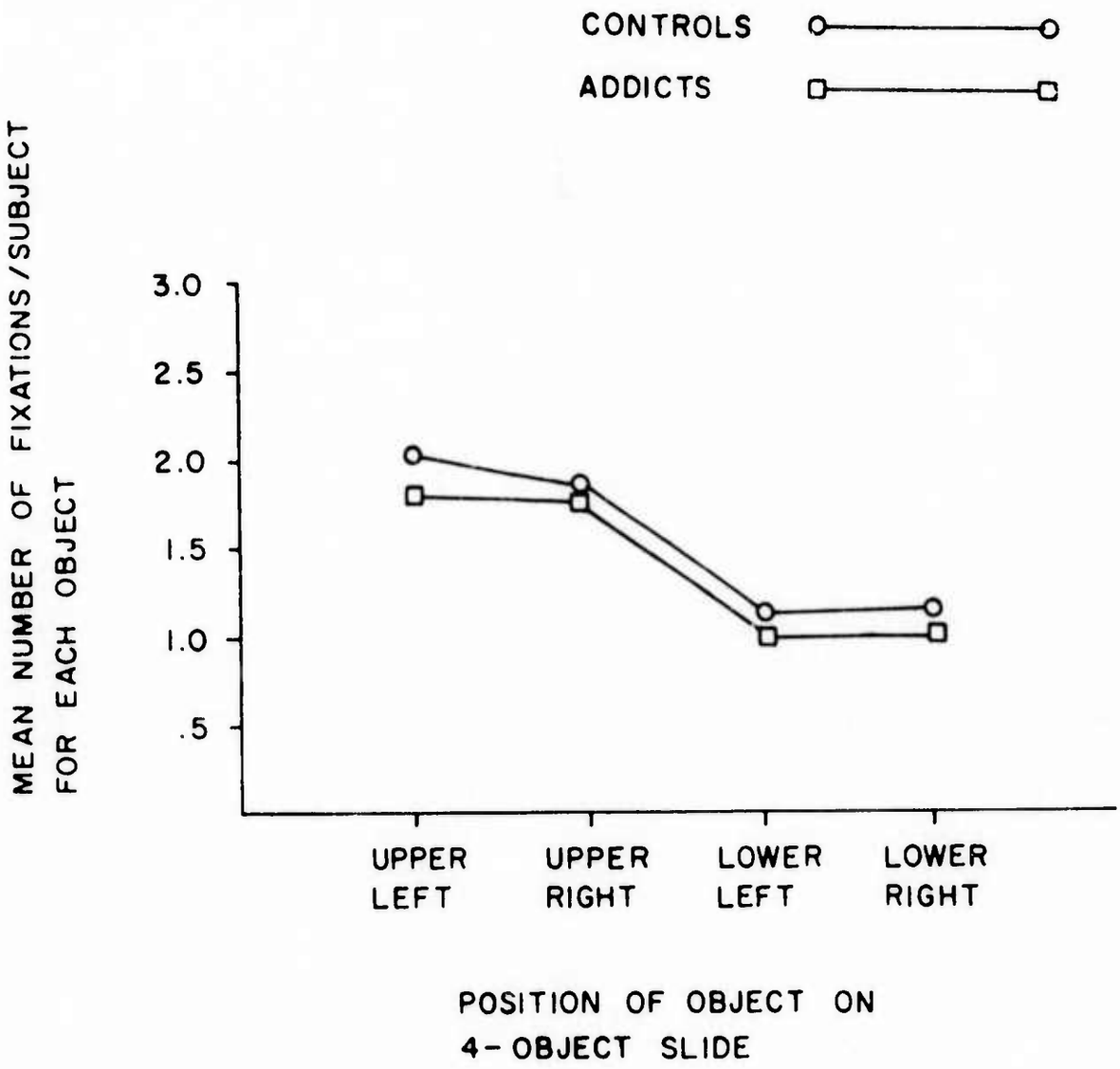

Fig. 13. The mean number of fixations for the object recall test are very similar to Figure 11 of the word recall test and although the differences between the drug and control subjects are not as pronounced they are significant at the .001 level. (The differences of the upper and lower position on the screen are due in part to accuracy with which the eye is tracked by the oculometer. As in Figure 11, a spatial boundary criterion of 17x and 35y was used to define a fixation.)

significant, $F(3, 132) = 59.66$, $p < .001$. The difference score analysis in which the addict and control subjects' average fixation duration for neutral objects is used to compute a difference score for his average fixation duration for all critical items shows that addict and control subjects differ significantly, $F(1, 44) = 12.81$, $p < .001$, in their response to drug items.

Both groups spend more time viewing drug objects than neutral objects, but the addicts' looking time for these items is significantly longer than that of the controls. For addicts, the difference between the average fixation duration for neutral items and drug items is approximately 30 frames/item; for the controls, this difference is 15 frames/item (sig. .001).

Conclusions: Object Recall Test

The results of the object recall test are similar to those obtained in the first and second versions of the word recall test. For example, the significant difference in the frequency and duration of fixation are in the same direction and order as those obtained in the word recall test. A somewhat more detailed analysis of differences in fixation duration indicates that the differences between addicts and controls for fixation duration are more pronounced for the drug objects than the neutral objects.

Split Word Recognition Test

The objective of the split-word test was to use a stimulus situation which would elicit rapid scanning by the subjects. In this experiment, the subject was told that the task was a word recognition test. The letters of the words were split into four groups and placed at four separate points on the screen like the word "pencil" shown below:

P EN
CI L

The subject was then told that as soon as he recognized the word, he was to press the hand-held response button and to say the word aloud.

A fixation slide with an X in the center preceded each split word. The subject was instructed to watch this slide until he was told by the experimenter to press the hand-held response button. This response removed the fixation slide and introduced a new split word slide for the subject to recognize and respond to. When he had recognized the split word and pressed the button, the slide was changed and a new fixation slide appeared.

There were 36 words in each session of the split word recognition test and the format was identical for both Sessions I and II. Two classes of words were used in this test, a group of twelve neutral words and a group of twenty-four drug-related words. The drug words were further divided into four groups (1) words that referred to heroin, e.g., stuff, junk; (2) words that referred to other drugs, e.g., weed, acid; (3) words that referred to drug dealers, e.g., lactose, cowboy; and (4) words that referred to police and law enforcement, e.g., narc, busted.

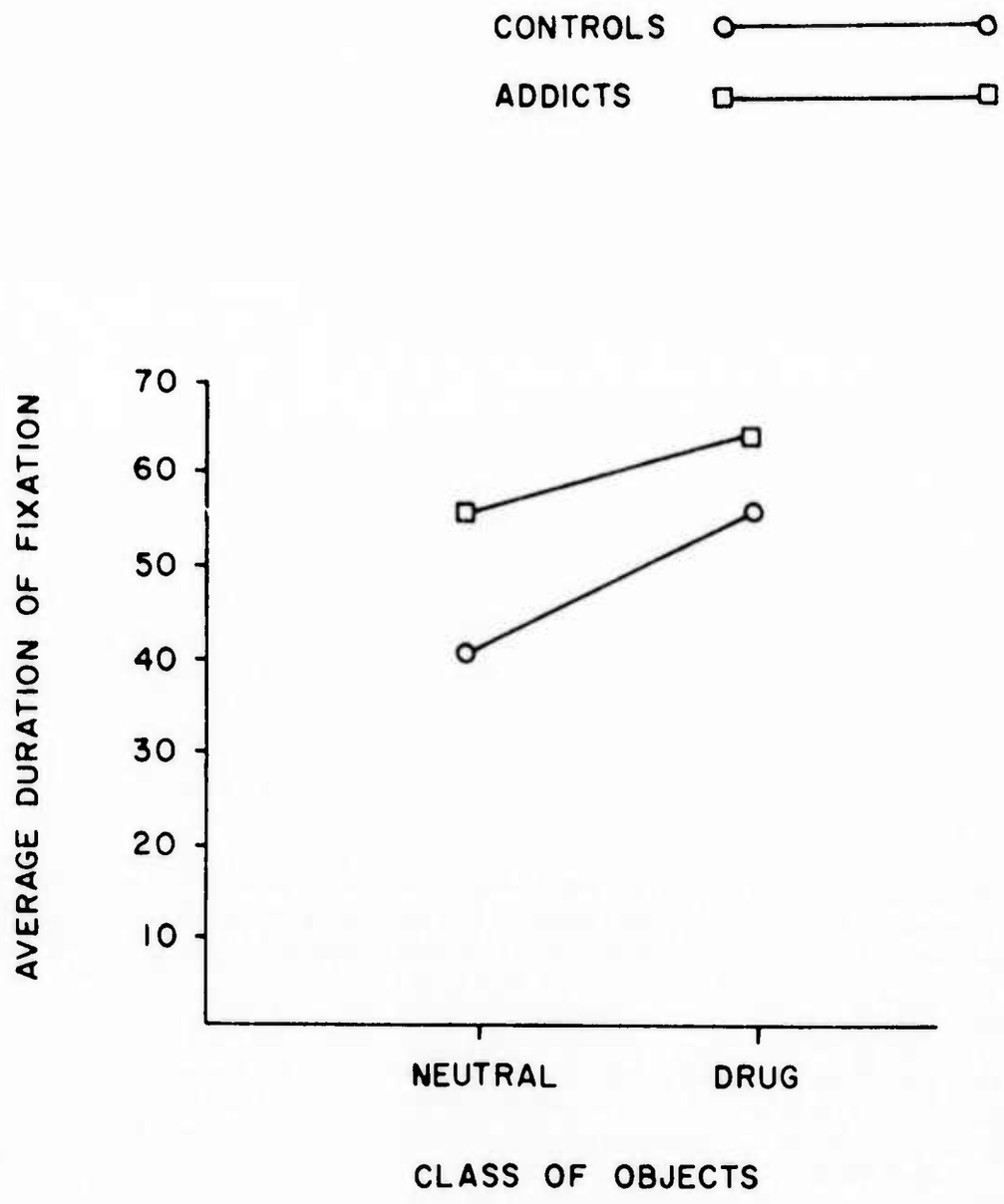

Fig. 14. This figure shows the differences between addicts' and controls' average fixation duration on the recall portion of the object recall test. (A comparison with the recall portion of the word recall test indicates that the controls' fixation duration for neutral objects are similar to neutral words, however fixation durations on neutral objects are longer than words for the addict groups, and average fixation duration for drug objects are considerably longer than words for both groups.)

Results: Split Word Test, Session I

A boundary criterion of 4x, 7y was used to process the data in this test. The measures of performance used to evaluate the data were fixation frequency and total looking time (i.e., the total recorded time that the subject looked at the slide before recognizing the word and pressing the response button). An analysis of variance performed on the data revealed a significant difference between the drug and control groups for two variables. The analysis of total looking time showed that the addicts take longer times to recognize the word than the controls, $F(1, 44) = 7.04$, $p < .05$, irrespective of the class of word. The analysis of fixation number revealed that the addicts had a significantly larger number of fixations, $F(1, 44) = 6.23$, $p < .05$.

Conclusions: Split Word Test

The differences in total looking time and mean number of fixations are similar to those obtained in self-paced portions of the word recall test and probably reflects the fact that the addicts are slower and take longer on this task.

There are indications that there are also differences in average fixation duration however, they were not significant. Since the analysis of the split word data is incomplete, it is too early to assess the value of a task requiring rapid scanning. However, there is evidence that the more leisurely observation task such as the observation portion of the word recall task may provide better data than a rapid scanning task.

DISCUSSION

Approximately 3,159,648 frames (60 frames a second) of good eye movement data have been collected and approximately 80 percent of this data has been partitioned by two boundary criterions which tend to optimize differences occurring in fixation duration (17x and 35y) and fixation number (4x and 7y). This portion of the data has then been transferred to a format suitable for a statistical analysis and processed.

The eye movement data analyzed was fixation frequency, fixation duration, and the scanning behavior between stimuli. A between groups analysis (controls vs. addicts) and a difference score analysis (subject's visual responses to neutral vs. non-neutral stimuli) revealed that the visual behavior of addicts differed from controls in two important ways. First, the between group analyses show that in all of the visual tasks analyzed thus far, the addicts differed significantly from the controls in their basic scanning behavior and information sampling rate (fixation frequency and duration). This result may be due in part to some basic physiological process probably having to do with the effects of drugs on the central nervous system.

Recent experiments dealing with early visual experiences in lower mammals have demonstrated specific and permanent changes in the structure and biochemistry of the central nervous system. In a recent article, "Experience and Plasticity of the Central Nervous System," Horn, Rose and Patterson (1973) discuss experimental evidence which indicates that neural mechanisms progressively loose their plasticity. They further suggest that one of the factors responsible for the structuring or loss of plasticity is visual experience. For example, they cite Spinelli, et.al., (1972) who has shown that once the receptive field of a neuron in the visual cortex of a kitten has been modified, the receptive field is not subsequently changed by new visual experiences. As Horn, Rose and Patterson point out when such changes occur at first order

neurons who respond selectively to simple stimuli such as angles or lines, the morphological and functional properties may be rigorously defined and the results long-lasting but non-specific. In other words, the specific effects on visual processes as in the case of humans who have had uncorrected astigmatic vision since birth may not produce a noticeable difference in their performance on complex visual tasks. If after a long period, even though the astigmatic error is optically corrected, their functional acuity does not improve because the morphological properties of the visual system and the functional properties of the central nervous system have been molded by the astigmatic inputs and are incapable of utilizing the information in the optically corrected stimuli. In the case of heroin, we might find a similar effect; for example, the recent studies of neuroanatomical correlates of morphine dependence (Wei, Loh and Way, 1972) and the demonstration of an opiate receptor in nervous tissue suggest the site of drug action is highly localized and specific. Heroin's effect on the central nervous system structure and sensory function might be highly specific but go unnoticed because it does not alter performance noticeable on complex tasks. However, use of an oculometer that can record and process the rapid eye movements associated with fixations might reveal such differences.

If the effects of heroin were highly specific in terms of the temporal processes which govern and regulate factors such as excitability cycles and cortical scanning (Harter, 1967), we might not observe a general effect on complex tasks. However, the gating and timing devices which group incoming sensory data for some type of central scanning mechanism could still be significantly altered. The results from our studies suggest that in the case of the addict there may be disturbances of temporal processes which gate and sequence successive fixations.

It is interesting to note that during the standard acuity check prior to experimentation, many addicts volunteered a variety of diffuse complaints about their vision even though they tested 20-20. When examining results of the difference in eye movements between the addicts and controls, it would seem well to be aware of the fact that we might be dealing with changes in the central nervous system which are specific and long-lasting but not easily observable as a general effect on complex tests. When the results of the visual and cutaneous data area taken together, there is room for speculation that the addicts demonstrate an altered sensory capacity in the temporal domain which has to do with the gating and subsequent scanning of stimuli.

Other investigators have also reported sensory differences between drug addicts and controls. For example, in a study of taste thresholds in addicts and alcoholics, S. E. Smith (1972), reports that the taste threshold for quinine is significantly lower for addicts than for controls or alcoholics. Although there is a strong suspicion that some structural or physiological factor may be operative, the difference score analysis provides ample evidence that the motivational factors associated with the importance of the stimulus material played a major role. Likewise, the word recall and split word test suggest that a difference in reading skills and the ability to manipulate printed material may also contribute to the differences in eye movements of the addict and control groups.

CONCLUSIONS

The major conclusions from this series of experiments fall into two areas: (1) basic differences between the eye movements of addicts and non-addicts and how these differences can be used to study the effects of drugs and detect their use, and (2) the utility of the oculometer system for investigating eye movements and their relationships to complex visual processes.

As a whole, this series of experiments demonstrate that the measurement of eye movements by the EG&G/HEL oculometer indicated basic differences in the sensory processes of the addicts and controls and that their eye movements associated with drug objects and words can be used to discriminate addicts from non-addicts. In those experiments where addicts and control subjects were viewing a series of slides containing neutral and critical items, it was demonstrated that a significant difference existed between the two groups for fixation number and for fixation duration. These differences appear to be due to two factors: (1) the differences in the central nervous system and visual mechanisms that direct and control rapid eye movements associated with fixation sequences, and (2) motivation or interest factors associated with drug words and objects. For example, in the word recall test which involved the visual responses of addicts and control subjects to slides containing neutral, drug, and dirty words, the addict groups' average fixation durations were substantially longer for drug and dirty words than neutral words. The eye movements of the non-addict controls demonstrated no difference between neutral, drug, or dirty words.

Since these results were replicated in a second version of the word recall test given on a different occasion and since similar results were found for the object recall test which employed neutral and drug objects, we have concluded that a reliable test battery could be developed that would screen individuals who are drug users.

In addition to the differences in fixation duration and frequencies which appear to be a consequence of the motivational aspect of drug words and objects, there appear to be basic differences between the sensory process of addicts and controls that may reflect fixational or structural differences in the central nervous system. For example, the dynamic test of cutaneous sensitivity (subject's ability to detect the direction of a moving point on the cutaneous surface) indicated that addicts require more sensory data before they can determine direction in which the point is moving. An analysis of error scores (choosing the wrong direction of movement) indicated that the differences between the groups were not caused by a criterion or motivational factors. Comparison of cutaneous and eye movement data suggests that as a group, the addicts take longer (longer fixations, greater distance traveled on the skin) to obtain the same sensory information as the controls.

Although the differences between the addict and controls' eye movements are substantially greater for drug stimuli than neutral stimuli, a smaller consistent difference is observed on portions of the visual tasks that contain only neutral stimuli. These consistent differences in fixation duration for neutral items suggest that there may be disturbances of the temporal processes which gate and sequence successive fixations. A research program should be developed that would investigate the basic differences between addicts' and non-addicts' sensory processes. An expanded methodology should be employed which would include EEG evoked potential and autonomic responses, and the eye movement measures developed in the previous study.

Correlation of eye movement data and central nervous system data could be used to investigate the more permanent or long-term changes in the central nervous system and sensory processes as well as the effect of transient or short-term changes such as visual disturbances produced by a fragmented diurnal cycle and disturbed sleep patterns.

In summary, the major conclusions which we have drawn from this series of experiments are:

1. The subjects who served as drug users were in fact heroin addicts who required daily injections of heroin to maintain their adaptation level and prevent withdrawal symptoms.

2. There are major differences in the rapid eye movements and fixation sequences of addicts and controls when viewing neutral or drug words and objects.

3. These differences are due in part to motivational factors associated with the stimuli and are characterized by longer fixation durations and lower fixation frequencies for the addict group.

4. Replication of the word recall test using a second version and administered on a separate occasion to the same groups of subjects produced differences between the addict and control subjects in fixation frequency and duration which were almost identical to the results obtained on the first version of the test. In general, replication of the experimental tasks indicated that a reliable test using eye movements could be developed and that this test would discriminate accurately between drug users and non-users.

5. The present method of abstracting and partitioning the eye movement data only partially reflects the differences that exist between the scan patterns of the addict and control groups. Secondly, an additional investigation of the boundary criterion used to define a fixation should be initiated.

6. In addition to the differences in eye movement that appear to be a consequence of the motivational aspects of the stimulus material, basic differences in fixation frequency and duration remain for neutral material. These differences appear to be related to some basic difference in the temporal processes which gate and sequence successive eye fixations.

7. Major differences also exist between the addict and control subjects on dynamic tests of cutaneous sensitivity. Results on these tests indicate that the sensory processes of the addict require more information in order to determine the direction of the moving point on the skin. An analysis of error scores also suggest that the differences in cutaneous sensitivity are not due to criterion or motivational factors and that the differences in cutaneous sensitivity are a direct result of differences in sensory capacity.

8. A comparison of cutaneous and eye movement experiments indicates that differences in sensory processes between the addict and the control groups are in the same direction; namely, that the addicts take longer to obtain the same sensory information.

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APPENDIX A

SUMMARY OF MALE AND FEMALE ADDICT DRUG HISTORIES

The following summary is based on the drug histories of forty heroin addicts. Sixteen females and twenty-four males completed these histories prior to their participation as subjects in the experiments. The questions are arranged as they appeared in the actual drug history and the numbers in parentheses correspond to the percentage of male addicts that answered the questions in that fashion. The numbers not in parentheses indicate the percentage of females that answered the question in that particular fashion.

DRUG HISTORY

Addicts' Mean Age 25

1. Sex

24 a. Male

16 b. Female

2. Ethnic Background

(.96), 1.00 a. Caucasian

(.04) b. Black

_____ c. Mexican

_____ d. Oriental

_____ e. Other

3. Education

(.12), 0 a. Elementary grade (8 Or less)

(.12), .38 b. Some high school

(.46), .44 c. High School grad (or equivalent)

(.29), .18 d. Some college

_____ e. College grad

4. Marital Status

(.42), .25 a. Single

(.33), .50 b. Married

(.08), .12 c. Separated

(.17), .12 d. Divorced

_____ e. Widowed

5. Longest Run on Heroin

_____ a. Less than one month

(.12), .06 b. 1-6 mos.

(.21), .25 c. 7-12 mos.

(.21), .19 d. 13-24 mos.

(.46), .50 e. more than 24 mos.

6. Longest period narcotic-free on the street after first run (not counting hospital or jail)

(.38), .50 a. Less than one month

(.33), .38 b. 1-6 mos.

(.17), .06 c. 7-12 mos.

(.04), .06 d. 13-24 mos.

(.08) e. more than 24 mos.

7. Number of times you went voluntarily to a treatment center, or half-way house

(.33), .25 a. 0

(.29), .38 b. 1

(.33), .31 c. 2-4

.06 d. 4-7

(.04) e. more than 7

Note: With parentheses denotes percentage of male responses
Without parentheses denotes percentage of female responses.

8. Length of current run

.06	a. Less than one month
(.25), .38	b. 1-6 mos.
(.38), .12	c. 7-12 mos.
(.08), .19	d. 13-24 mos.
(.29), .25	e. more than 24 mos.

9. Spouse, boy(girl) friend addicted?

(.42), .62	a. Yes
(.46), .31	b. No
(.13), .06	c. No spouse or boy(girl) friend

10. Any other relative addicted?

(.79), .94	a. No
	b. Parent
(.21), .06	c. Brother or sister
	d. Child
	e. Other

11. Is Alcohol use a problem for you?

(.04)	a. Yes, now
(.25), .06	b. Yes, at one time but not now
(.71), .94	c. Never

12. How much do you drink in the morning?

	a. Often, almost every day
(.04), .06	b. Sometimes, a few times a week.
(.04)	c. Occasionally, less than once a week
(.38), .12	d. Rarely
(.54), .81	e. Never

13. Ever arrested for drunk driving or drunk in public?

(.67), .81	a. Never
(.12), .19	b. 1 time
(.21)	c. 2-4 times
	d. 5-10 times
	e. more than 10 times

14. Shot speed (mainline) greatest number of days in a row

(.46), .25	a. 0
(.12)	b. 1 day
(.21), .31	c. 2-4 days
(.04), .12	d. 5-7 days
(.17), .31	e. more than 7 days

15. Barbiturates to get high, total number of times

(.08), .06	a. 0
(.04)	b. 1 time
(.08), .25	c. 2-7 times
.06	d. 8-15 times
(.79), .62	e. more than 15 times

16. Smoked grass, total times

(.04)	a. 0
	b. 1-5 times
(.04), .06	c. 6-20 times
.19	d. 21-50 times
(.92), .75	e. more than 50 times

17. Used LSD, total times

(.08), .25	a. 0
(.25), .31	b. 1-5 times
(.04)	c. 6-10 times
(.08), .18	d. 11-20 times
(.54), .25	e. more than 20 times

18. Working now? How long on this job?

(.54), .81 a. not working

b. less than one month

(.17) c. 1-6 months

(.08), .06 d. 6 mos.-1 yr.

(.21), .12 e. more than 1 yr.

19. Number of different jobs in past five years

(.08) a. 0

(.08), .06 b. 1

(.21), .19 c. 2

(.29), .44 d. 3-5

(.33), .31 e. more than 5

20. Longest time one job at any time in the past

(.21), .31 a. Less than 6 mos.

(.29), .44 b. 6 mos.-1 yr.

(.17), .19 c. 1-2 yrs.

(.29), .06 d. 2-4 yrs.

(.04) e. more than 4 yrs.

21. On Welfare?

(.04), .06 a. Yes, now

(.08), .38 b. Not now, but was on at one time

(.88), .56 c. Never

22. Number of times arrested and charged in PAST YEAR

(.38), .38 a. 0

(.25), .19 b. 1 time

(.12), .12 c. 2 times

(.08), .12 d. 3-5 times

(.17), .19 e. more than 5 times

23. Number of times picked up, but not charged with anything, in PAST YEAR

(.58), .56 a. 0

(.17), .06 b. 1-2 times

(.17), .12 c. 3-5 times

(.08), .06 d. 6-12 times

.19 e. more than 12 times

24. Number of DRUG CONVICTIONS in your whole life

(.62), .69 a. 0

(.25), .06 b. 1

(.04), .12 c. 2

(.04), .06 d. 3-5

(.04), .06 e. more than 5

25. Number of convictions on other charges (NOT DRUGS) in your whole life

(.29), .50 a. 0

(.29), .06 b. 1

(.17), .06 c. 2

(.17), .31 d. 3-5

(.08), .06 e. more than 5

26. Do you agree that heroin would be OK if it were legal (for your own use)?

(.67), .31 a. Yes

(.33), .69 b. No

27 At present are you taking heroin more to get high, or to keep from getting sick?

(.12), .19 a. To get high

(.46), .31 b. To keep from getting sick

(.42), .50 c. Both reasons

28.. Write age of first use of heroin or any narcotic like heroin

(17.08), 17.25

29. Write age of first run (daily use) on heroin or any narcotic like heroin

(18.125), 17.875

APPENDIX B

THE EG&G/HEL OCULOMETER[1]

For electro-optical sensing of eye position without attachments or head constraints utilization of the corneal reflection and the pupil centers as references, probably represent the best techniques available today. Under good conditions, their accuracies are approximately ± 1 to 1.5 degrees. The scan range is limited to ± 12 degrees; however, the recording can be sustained at this level of accuracy for long periods of operation. This measurement technique does not interfere with subject's normal eye movements and it does not require the subject to be familiar with or aware of the eye measurement device. Individual differences which affect the technique are essentially the same as those that interfere with the recording of corneal reflection (e.g., astigmatism and nonlinearities in the cornea). Factors which can influence the accuracy of recording corneal reflection are:

a) head movement,

b) changes in the thickness of the tear fluids,

c) astigmatism of the cornea (e.g., the vertical meridian has greater curvature than the horizontal meridian),

d) individual difference in cornea shape, and

e) eyeglasses whose optical surfaces produce additional highlights.

Some of the nonlinearities and irregularities in the cornea surface can be eliminated by calibration procedures; nonetheless, the relationship between the movements of the reflection and the eye movement is a complicated one and requires special computations to eliminate these nonlinearities.

Figure 1B is a functional block diagram of the present system for monitoring eye movements. Block No. 1 (Fig. 1B) consists of the experimental room where the subject is comfortably seated viewing a projection screen approximately six feet away. No attachments in the form of head stabilization or eye movement transducers are placed on the subject. Polarized lighting surrounds the viewing screen in the wall. A small non-polarized portion of the lighting surrounding the screen light produces a clearly defined highlight that is reflected from the front surface of the subject's cornea. The subject's eye behavior is monitored by a concealed optical relay system Block No. 2 and low light level TV camera Block No. 4 which is mounted below the projection screen.

[1]EG&G refers to the Company, Special Projects Division, Las Vegas, Nevada, and HEL refers to Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, both of which are responsible for the development of the Oculometer System used in this experiment.

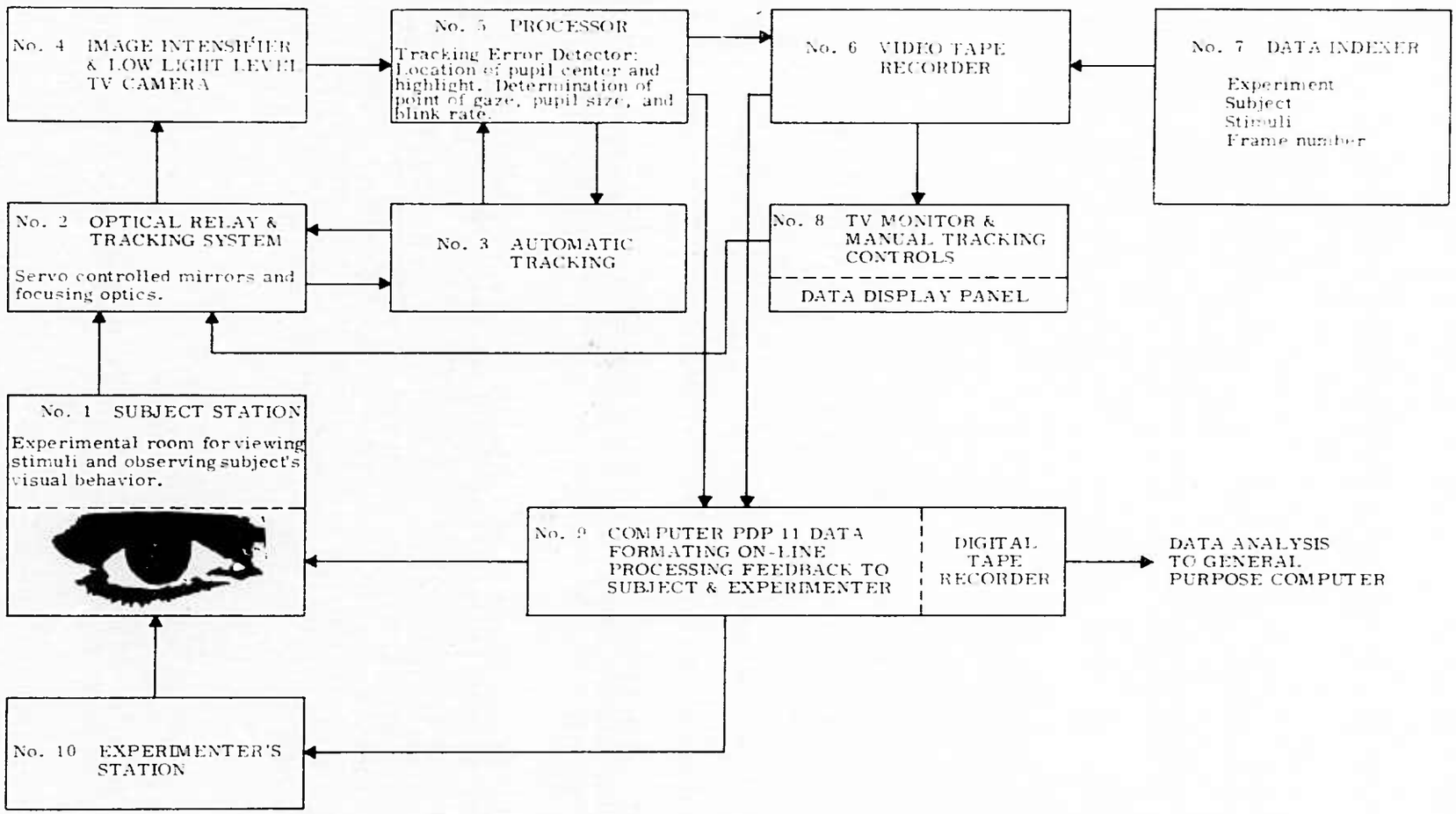

Fig. 1B. Functional block diagram of the present EG&G/HEL apparatus for observing visual behavior.

The optical relay and tracking system performs two major functions. The first function is one of relaying information to the low light level camera. In this instance, the image of the eye and highlight go to the image intensifier and low light level camera. The second function, tracking the eye, is performed by a system of several mirrors and lens focusing mechanisms. These mechanisms keep the eye in focus and centered on the main viewing axis of the system. The control information for these servos which track the eye comes from Block No. 5, a processor which compares the x-y location of the highlight with the center of the pupil. This enables the system to determine the eye position and the point of gaze. Once the eye position is sufficiently far enough from the main viewing axis, the system realigns the two. Block No. 3 is primarily concerned with the position of the highlight in x and y and keeping the image properly focused. It feeds information to the processor.

In No. 5, the processor computes the point of gaze by determining the center of the pupil and the location of the highlight. This information can be recorded on digital video tape and displayed on the TV monitor No. 8. At this point, information concerning the subject, the stimulus situation, and the frame number are indexed on each frame (No. 7). The TV monitor shown in Figure 2B (No. 8) has manual tracking control which permits the operator to override the system in case the automatic tracker should fail to acquire the subject's eye properly.

Information concerning the eye's position and other behavior such as blinking and changes in pupil size are fed to the computer (No. 9) from the processor and (No. 5) and from the video tape recorder (No. 6). The main function of the computer (No. 9) is to provide feedback to the experimenter and format the data so that it can be analyzed by a general purpose computer. As the system continues to evolve, software and feedback mechanisms will be developed that can give immediate feedback to the subject or the experimenter concerning the subject's visual behavior.

Fig. 2B. Modified control room showing reduction capability employing a PDP-11 Computer.